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CH Chanbisana
Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India

AK Banik
Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India

H Prasad
College of Horticulture Thenzawl, Mizoram, Central Agricultural University Imphal, Manipur, India

Priyanka I
College of Horticulture Thenzawl, Mizoram, Central Agricultural University Imphal, Manipur, India

Yamuna P
College of Horticulture Thenzawl, Mizoram, Central Agricultural University Imphal, Manipur, India

Correspondence
CH Chanbisana
Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India

Evaluation of date of planting, head diameter and variety on post harvest quality of broccoli stored in room condition

CH Chanbisana, AK Banik, H Prasad, Priyanka I and Yamuna P

Abstract
An experiment was conducted to study the interaction effect of date of planting, variety, and head diameter on storage quality in the research farm at Mondouri on broccoli cv. Aishwarya and cv. Sadhana by sowing at 15th September, 30th September and 15th October and harvesting at three head diameters: ≥12<14cm (small), ≥14<16cm (medium) and above 16cm (large) and stored at room condition (15 to 25ºC with 45 to 70%RH) after packing in polypropylene bags 100 gauge. Small size broccoli gave least loss in weight during the storage period of 3 days. Medium size broccoli Sadhana sown at 15th September gave the highest soluble solids content while ascorbic acid content was highest in 15th September sown broccoli Aishwarya with medium head size at the end of storage period. During storage broccoli retained appreciable amount of ascorbic acid though yellowing started. Thus broccoli sown early at 15th September gave higher marketability on the last day of storage in variety Aishwarya with smallest head diameter of ≥12<14cm in respect storage quality.

Keywords: aishwarya, ascorbic acid, broccoli, chlorophyll, sadhana, yellowing

Introduction
Broccoli (*Brassica oleracea* L. var. *italica* plenck.) is also known as calabrese or green sprouting broccoli, Italian broccoli, asparagus broccoli, belongs to family Brassicaceae, a cool season crop and closely related to cauliflower. Broccoli is an important vegetable because of the anticarcinogenic glucosinolate presence and it is a new introduction to India. India is the second largest producer of broccoli after China, while the US ranks third. It is highly valued due to its richness in vitamins, antioxidants, anticarcinogenic compounds (Nestle, 1998) [11] and health promoting phytochemicals (Yuan *et al.*, 2010) [22]. In West Bengal, broccoli is less popular among vegetable growers. However, researchers/farmers experience revealed that this nutritious exotic vegetable could be grown in the state with temperature ranging from 12-26^{0}C with humidity range 53-95% and 0.44-6.95mm rainfall during winter season, without much difficulty. Broccoli consists on an average 88-89% water, 2.8% proteins, 0.4% lipids, 6.6% carbohydrates, 1.7% total sugars, and 2.6% fibre. The main sugars of broccoli are glucose (0.58-0.84g/100g fresh weight), fructose (0.7-0.93g/100g fresh weight), and sucrose (0.07-0.18g/100g fresh weight), with maltose (0.21g/100g fresh weight) and lactose (0.21g/100g fresh weight) present in smaller amounts. Loss of quality in broccoli during storage usually results from wilting, yellowing of the buds and florets, loosening or opening of the head and decay (Toivonen and Forney, 2004) [17]. Temperature is the most important environmental factor, as it affects the rate of postharvest deterioration from all causes (Wills *et al*., 2007) [18]. Many more growers are coming to broccoli production/trade as they bring good income and the demand in hotels, restaurants and markets are increasing. But it is highly perishable, there arise problem in post harvest management during handling as it has short shelf life thereby short period of availability and there is scanty information on post harvest technology aspect of this crop. It is harvested when the floral heads, branchlets, and florets are totally immature, with sepals completely surrounding the flower i.e., when still tight and compact. Generally the broccoli head with a small portion of the stalk is harvested. The heads are cut off with about 15cm of the stem attached after cutting, part of the foliage is removed from the harvested shoots. The head may be 15-25cm in diameter and weighs 250 to 600g so the research work was carried out to study effect in post harvest quality of broccoli when harvested at different head diameter and shown at different date of planting taking two varieties for consideration.

Materials and Methods

Cultivation was done in the Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal under sub tropical humid (Indo-Gangetic) agro climatic zone of West Bengal situated at 9.75m above mean sea level, latitude 23.5^0N and longitude 89^0E having sandy loam and sufficiently deep soil with pH slightly acidic to neutral i.e., 6.0 to 6.8, for two years 2013, 2014 consecutively and laboratory work was performed in the Department of Post Harvest Technology of Horticultural Crops, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal. Two varieties of broccoli *viz*., Aishwarya and Sadhana were considered for conducting the present research work. Aishwarya hybrid variety was procured through Bayer Crop Science Vegetable Seeds (originally Nunhems India Private Limited) Vivekananda Road, Kolkata-99, while seeds of variety Sadhana was procured from Known-You Seed India Private Limited.

The meteorological data was recorded for maximum, minimum temperature, relative humidity, total rainfall and bright sunshine hour during the crop growth for the year 2013-14 in the Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal in field condition were collected from the Department of Agricultural Meteorology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal. Crop cultivation was carried out following standard packages and practices. Broccoli heads were harvested from field at different head size for the two varieties and brought to the laboratory immediately in plastic crates and kept for 3hrs in room condition. Then they were trimmed and packed in polypropylene bag 100 gauge and stored in room condition for both the varieties harvested at different head sizes from different dates of planting as described below:

Treatments:

Head diameter: H_1: ≥12 <14cm (small), H_2: ≥14 <16cm (medium), H_3: 16cm and above (large)
Variety: 2 i.e., V_1=Aishwarya, V_2=Sadhana
Date of sowing: D_1=15th September, D_2= 30th September, D_3=15th October
Experimental design: Factorial CRD
Number of replication: 3
Number of factor: 3

Observations recorded: Physiological loss in weight (%), ascorbic acid (mg/100g), TSS (ºB), Chlorophyll(µg/g), yellowing (%) and marketability were estimated during the period of storage by following standard procedures as described under physico-chemical analysis in room condition (one day interval).

Physical and chemical analysis

Physiological loss in weight (%): PLW was calculated as cumulative % loss in weight, based on the initial weight (before storage) and loss in weight was recorded at the time of periodical sampling during storage (Nath *et al*., 2011) [10].

$$\text{PLW} = \frac{\text{initial weight} - \text{finalweight}}{\text{initial weight}} \times 100$$

Ascorbic acid: Volumetric method of ascorbic acid determination (2,6- Dichlorophenol-Indophenol Visual Titration Method) was done using 2, 6-dichlorophenol indophenols.

$$\text{Ascorbic acid (mg/100 g)} = \frac{\text{Titre value} \times \text{Dye factor} \times \text{Volume made up}}{\text{Aliquot of extract taken for estimation} \times \text{Wt: or vol: of the sample taken for estimation}} \times 100$$

Total soluble solids (TSS) °Brix: ºBrix is used as an indicator of total soluble solids in the juice of fruits and vegetables. A few drops of broccoli juice were on the prism for each sample for estimating the TSS (Erma Hand Refractrometer I.S.O 2173).

Chlorophyll: Total chlorophyll content was determined by spectrophotometric method. A known amount of broccoli sample by weight is taken and chlorophyll is extracted in 80% acetone until the residue has no more green colour. The filtrate or supernatant is made upto known volume with 80% acetone and the Optical Density (OD) value is then measured through 660nm and 642.5nm wavelength in a colorimeter against blank. Using the adsorption coefficients, the amount of chlorophyll is calculated as follows:

Total chlorophyll (a+b), µg/ ml = (7.12 × OD at 660nm) + (16.8 × OD at 642.5nm)

Yellowing percentage: The area which becomes yellow is recorded visually and according to it, the yellow area is calculated in percentage.

Results and Discussion

Physiological loss in weight (%): Influence of different dates of sowing gave significant difference on the physiological loss in weight of broccoli in Table 1 during the 3 days' storage study. The weight loss increased with the progress in storage period. The minimum loss in weight was recorded in mid sown broccoli at 30th while the maximum loss in weight throughout the storage study was observed in late sown crops at 15th October. The minimum loss in weight was noted in Sadhana (V_2) with 0.87% while maximum loss in weight was recorded in Aishwarya (1.09 to 1.31%) during the storage period.

Head diameter gave significant effect on physiological loss in weight of broccoli which increased with the progress of storage. Higher loss in weight was recorded in large size head (H_3) while minimum values of PLW (0.50 to 0.88%) were recorded in broccoli with small head size (H_1) during the period of storage.

There was no significant effect of interaction of date of sowing, variety and head diameter on the loss in weight of broccoli during the first two days of storage while it showed significant effect on day 3. The least values of loss in weight (0.13 to 0.30%) were noted in broccoli var. Aishwarya sown at 15th September having small head diameter throughout the storage period while the maximum loss (1.60 to 2.57%) was indicated in mid sown Sadhana with large head diameter ($D_2V_2H_3$) during the storage period.

The weight loss was lowest in the small head diameter-H_1 (0.88%). The higher loss in weight in large head diameter- H_3 than others is due to larger surface area resulting in higher water loss from the surface compared to the smaller ones due to respiration and transpiration. High weight loss is a significant problem of stored broccoli florets for marketability (Serrano *et al*., 2006) [14].

Mid planting (sown at 30th September) resulted in lower PLW throughout the storage period which can be best explained by

the prevailing lower temperature during the storage. Sadhana possessed lower PLW than Aishwarya in the storage.

Broccoli harvested at all the three head diameters followed increasing trend for the 3 days' storage period due to the continued biological process of rapid respiration of fresh produce where the water content is high (88-89%). Nath *et al.* (2011) [10] reported that broccoli in ambient condition showed continuous increase in PLW because of continuous loss of moisture due to transpiration and respiration and reported maximum weight loss in uncovered broccoli while Cheng *et al*. (2009) [3] found that the loss in weight of the packed broccoli in bags were significantly reduced to below 4% by the end of storage at 20ºC which support the current finding and the best was the small head diameter-H_1 which may be due to lower transpiration and respiration rate attributed to lesser surface area. The higher weight loss was evident in Sadhana than Aishwarya during the period of study and the best interaction effect with lowest weight loss was in early sown (15th Sept) broccoli Aishwarya having small head diameter of 12-14cm ($D_1V_2H_1$) for the period of study.

Marketability (%)

On the last day of the storage period, marketability was analysed on quality basis of visual observation and acceptance to consumer in Table 1. Early sown broccoli at 15th September showed higher marketability and marketability decreased with the late sowings.

Variety Aishwarya showed higher marketability than variety Sadhana due to varietal character which correlates with the results of the experiment. Small size broccoli of ≥12<14 cm(H1) head diameter showed higher marketability than medium and larger head diameter due to lesser loss of moisture and intact features. Interaction effect of date of sowing, variety and head diameter resulted in higher marketability in Aishwarya sown at 15th September with 14 to 16cm head diameter.

TSS (ºB): Significant difference of TSS was not evident due to different dates of sowing of broccoli during storage study in Table 2 though there was reduction in TSS content with the progress of storage duration. Maximum value of 7.88^{0}B was found in broccoli sown at 30th September (D_2) throughout the period of storage while the minimum value of 6.57^{0}B was recorded in late sown broccoli at 15th October.

Variety showed significant differences on the total soluble solids content of broccoli during the storage period except on day 2 only. The value followed decreasing trend during the storage period but the value remained higher in Aishwarya (7.78 to 6.95^{0}B) compared to Sadhana (7.18 to 6.70^{0}B) during the period of study though it declined on the last day of storage.

TSS content due to head diameter was not significant except on day 3. Maximum values (7.48 and 6.96ºB on 1 and 3 days after storage) were observed in broccoli harvested at medium head diameter, ≥14<16cm (H_2) whereas the minimum TSS contents (7.09 and 6.73ºB) were recorded in small size head, 12 to 14cm (H_1).

The interaction effect of date of sowing, variety and head diameter have no significant influence with respect to TSS except on day 2 and 3. Late sown cv. Sadhana having medium head size ($D_3V_2H_2$) recorded the highest TSS of 7.17ºB on day 3 while the minimum TSS value of 6.27 ºB was observed in late sown Aishwarya having medium head ($D_3V_1H_2$) at the end of storage.

Mid sowing at 15th Sept (H_2) showed better TSS content compared to those sown at early sowing (H_1) and late sowing (H_3) in Table 2. Aishwarya variety possessed better TSS value than Sadhana. Medium broccoli head (H_2) maintained better quantity of TSS during the period of storage though the highest value was seen in small head- H_1 and the best interaction effect was seen in mid sown Sadhana having medium head ($D_2V_1H_3$).

Generally, soluble solids increase with postharvest elapsing time by the progress of biosynthetic processes or by degradation of the cell wall polysaccharides (Puerta and Cisneros, 2011) [13] which is in contradiction with the current finding of decreasing soluble solids contents during the storage period where the trend of decreasing TSS may also be attributed to intense proteolysis occurs during postharvest senescence of broccoli, resulting reduction in protein content (Page *et al*., 2001) [12]. Reduction in TSS may be due to normal post harvest physiology of broccoli during air storage as characterised by the rapid loss of sucrose from the florets which was recorded by Downs and Somerfield (1997) [6]. Decreasing trend in TSS may be correlated with the finding of Mahfuzah *et al.* (2013) [8] showing decreasing TSS value in strawberry. The decline in the sugar content at the later stages of storage may be attributed to the fact that after the completion of hydrolysis of starch, no further increase in sugars occurs and subsequently a decline in sugars is predictable as they along with other organic acids are primary substrate for respiration (Wills *et al*., 1980) [19].

Ascorbic acid

The influence of date of sowing on the ascorbic acid content of broccoli was significant from day 2 of the storage period in Table 3. Highest amount of ascorbic acid (119.17 to 91.78mg/100g) was recorded in mid sown broccoli at 30th Sept. while the minimum content (115.15 to 64mg/100g) was observed in early sown broccoli during the storage period.

Significance of variety on ascorbic acid content revealed the maximum ascorbic acid content throughout the storage period in broccoli var. Aishwarya.

Ascorbic acid content due to head diameter was not significant except on day 3. Maximum value of 86.14mg/100g was observed in broccoli harvested at medium head diameter, ≥14<16cm (H_2) whereas the minimum ascorbic acid content of 70.19mg/100g was recorded in large size head, above 16cm (H_1).

Interaction effect of sowing date, variety and head diameter did not show any significant difference except in day1. Maximum ascorbic acid content (110.66mg/100g) was noted in mid sown broccoli var. Sadhana with medium head diameter ($D_2V_2H_2$) whereas the minimum ascorbic acid content (56.33mg/100g) was observed in early sown Aishwarya with large head diameter ($D_1V_1H_3$) on the last day of storage period.

Mid sown broccoli at 30th September (D_2) gave good amount of ascorbic acid among the treatments which may be attributed to the favourable condition prevailing for the growth. Aishwarya had more ascorbic acid content than Sadhana due to the cultivar inheritance. Fair amount of ascorbic acid was maintained in broccoli having small and medium head diameter during the 3 days' storage while the best interaction effect was seen in mid sown Sadhana with medium head diameter ($D_2V_2H_2$).

The ascorbic acid decreased for all the treatments during the storage which is supported with the findings of Nath *et al*. (2011) [10] where the initial ascorbic acid content of fresh broccoli florets was found to be 130 mg/100g and it decreased linearly during storage under different treatments. The progressive decline of ascorbic acid was supported with the finding of Serrano *et al*. (2006) [14] and Yan & Liu (2012) [21].

Chlorophyll (µg/g)

Mid sown broccoli at 30th September (D_2) have higher chlorophyll value (192µg/g) while the lowest chlorophyll content (181µg/g) was recorded on day of harvest and 3 days after storage in Table 4. The decrease among them was significant on day 1, became non significant on day 2 after which the decreasing trend became significant on day 3.

Variety gave significant effect on chlorophyll content during the storage period. Broccoli cv. Sadhana gave higher chlorophyll content (198.43µg/g) compared to Aishwarya which retained lower chlorophyll content (174.67 µg/g) at the end of the storage period

There was significant effect of broccoli head diameter on chlorophyll content during storage period resulting in maximum chlorophyll content of 195.51µg/g in small, ≥12<14cm head diameter **(**H_1) while minimum content (172.78 µg/g) was observed in large broccoli with above 16cm head (H_3) with the end of the storage period.

The interaction effect of head diameter, variety and date of planting indicated significant effect on 1 and 2 days of storage. Maximum retension of chlorophyll (227.66 µg/g) was observed in Sadhana sown early harvested at small head diameter ($D_1V_2H_1$) on the last of storage while the minimum retension (133.66 µg/g) was noted in early sown broccoli cv. Aishwarya with large head diameter above 16cm ($D_1V_1H_3$) on the last day of storage. Throughout the storage period, the best amount of chlorophyll was maintained in Sadhana sown at 30th September harvested at ≥12<14 cm head diameter ($D_2V_2H_1$).

Broccoli sown at 30th September possessed better chlorophyll than the other during the 3 days storage period. Aishwarya, V_1 showed higher chlorophyll than Sadhana. The best interaction effect of date of planting, variety and head diameter was in Sadhana sown at 30th September with ≥12<14 cm(H1) head diameter, $D_2V_2H_1$. Chlorophyll content followed decreasing trend during the storage period.

Chlorophyll loss has been associated with lipid peroxidation (Zhuang *et al*., 1995) [23] and with enhancement of POD activity (Costa *et al*., 2006) [4]. Changes of chlorophyll level in photosynthetic cells are good indicators of senescence, occurring in green vegetables after harvesting. Chlorophyll content degradation increased with temperature in broccoli florets (Starzyńska *et al*., 2003) [15] and pakchoy leaves (Able *et al*., 2005) [1].

Yellowing (%)

Significant difference of yellowing (%) of broccoli occurred during the storage period due to the effect of dates of sowing of broccoli in Table 5. Yellowing percentage increased significantly during the storage period. Maximum yellowing occurred in broccoli sown late at 15th October, D_3 while the least yellowing was noted in early sown crop at 15th September and increased from 3.25 to 40% during the storage period.

In Table 5, variety showed significant variation in yellowing % with storage duration with higher value of yellowing in Aishwarya (V_1) with an increasing trend during the storage period compared to Sadhana (V_2) during the storage period.

It was clearly expressed that different head diameters gave significant variation of yellowing % in broccoli during the storage period with maximum yellowing in large head diameter above 16cm (H_3) with increasing values throughout the storage while the minimum yellowing was recorded in small head diameter of ≥12<14cm (H_1) during the storage period.

Interaction effect of date of sowing, variety and head diameter resulted in significant differences in yellowing percentage of broccoli during the storage period. Highest yellowing % occurred in mid sown broccoli cv. Sadhana with medium head size of ≥14<16cm($D_2V_2H_2$) while no yellowing % was recorded in late sown broccoli cv. Sadhana having small head diameter of ≥12<14cm ($D_3V_2H_1$) and large head diameter above 16cm ($D_3V_2H_3$)

The minimum yellowing was seen in those sown at 15th September, D_1 and maximum in broccoli sown at 15th October, D_3 while yellowing was higher in Aishwarya compare to Sadhana during the period of study and the best interaction reaction was seen in Sadhana sown at 15th October with ≥12<14cm head ($D_3V_2H_1$), Sadhana sown at 15th October with ≥14<16cm(H_2) head ($D_3V_2H_2$) and Sadhana sown at 15th October with above 16cm head ($D_3V_2H_3$). Makhlouf *et al*. (1989) [9] defined broccoli as a climacteric produce due to its respiration ratio and ethylene production increasing during senescence leading to yellowing of florets. The climacteric status of broccoli has also been confirmed by Tian *et al*., 1994. The colour changes of broccoli are related to the yellowing process of broccoli inflorescences and to the degradation of chlorophylls (Eason *et al*., 2007) [7]. Yellowing of leafy and green vegetables has been attributed to peroxidase after storage activity (Baardseth and von Elbe, 1989; Yamauchi and Watada, 1991) [2, 20] and lipoxygenase activity (Zhuang *et al*., 1995) [23]. The activities these two enzymes could be responsible for yellowing of broccoli. Costa *et al*. (2005) [5] gave evidence that broccoli at 20ºC showed increased chlorophyllase activity during the experiment, reached the maximum at 3 day and Mg-dechetalase activity also increased along the course of senescence while the peroxidase after storage-linked chlorophyll bleaching activity increased three times. Earlier sowing of the crop resulted in lesser amount of yellowing. So earlier sowing of the broccoli crop is preferable.

Table 1: Effect of date of sowing, variety, head diameter and their interaction on physiological loss in weight (%) of broccoli stored in room condition. (*Values in brackets are angular transformed data)

Date of sowing Variety Head diameter (cm)				**Marketability (%) on 3rd day**
Days in storage				
	1	**2**	**3**	
Effect of date of sowing				
15th Sept (D_1)	0.94(1.38)	1.23(1.48)	1.29(1.51)	66.17
30th Sept (D_2)	0.95(1.38)	1.03(1.42)	1.06(1.42)	55.28
15th Oct (D_3)	1.15(1.44)	1.22(1.48)	1.67(1.57)	55.28
Sem±	0.03	0.05	0.02	0.76
CD(P=0.05)	NS	0.15	0.15	2.19
Effect of variety				
Aishwarya (V_1)	1.09(1.43)	1.23(1.48)	1.31(1.48)	60.04
Sadhana (V_2)	0.87(1.35)	1.22(1.48)	1.30(1.49)	57.78
Sem±	0.07	0.04	0.02	0.62
CD(P=0.05)	0.07	NS	NS	1.79

Effect of head diameter						
≥12<14(H_1)			0.50(1.22)	0.62(1.27)	0.88(1.36)	70.61
≥14<16(H_2)			0.99(1.40)	1.05(1.43)	1.46(1.50)	54.44
Above 16 (H_3)			1.39(1.54)	1.6(1.60)	2.06(1.70)	51.67
Sem±			0.03	0.05	0.02	0.76
CD(P=0.05)			0.90	0.15	0.06	2.19
Effect of interaction						
		≥12<14(H_1)	0.63(1.27)	0.97(1.40)	1.37(1.54)	53.67
15th Sept (D_1)	Aishwarya (V_1)	≥14<16(H_2)	0.66(1.28)	1.24(1.49)	1.65(1.59)	88.33
		Above 16 (H_3)	0.60(1.26)	1.37(1.54)	1.67(1.63)	83.33
		≥12<14(H_1)	0.13(1.06)	0.23(1.11)	0.30(1.14)	76.67
15th Sept (D_1)	Sadhana (V_2)	≥14<16(H_2)	0.83(1.35)	1.07(1.44)	1.20(1.48)	51.67
		Above 16 (H_3)	1.13(1.46)	1.43(1.56)	1.77(1.66)	43.33
		≥12<14(H_1)	0.60(1.26)	0.83(1.35)	1.03(1.43)	61.67
30th Sept (D_2)	Aishwarya (V_1)	≥14<16(H_2)	0.67(1.29)	0.92(1.38)	1.29(1.51)	48.33
		Above 16 (H_3)	1.33(1.46)	1.69(1.70)	2.27(1.78)	46.67
		≥12<14(H_1)	0.33(1.15)	0.37(1.17)	0.47(1.21)	8.00
30th Sept (D_2)	Sadhana (V_2)	≥14<16(H_2)	1.10(1.45)	1.33(1.52)	1.97(1.72)	48.33
		Above 16 (H_3)	1.60(1.61)	1.70(1.64)	2.57(1.88)	46.67
		≥12<14(H_1)	0.70(1.30)	0.83(1.35)	1.30(1.52)	70.00
15th Oct (D_3)	Aishwarya (V_1)	≥14<16(H_2)	0.82(1.35)	0.87(1.36)	1.83(1.66)	43.33
		Above 16 (H_3)	0.80(1.34)	1.23(1.490	1.37(1.53)	45.00
		≥12<14(H_1)	0.17(1.08)	0.83(1.35)	0.97(1.40)	81.67
15th Oct (D_3)	Sadhana (V_2)	≥14<16(H_2)	1.00(1.41)	1.20(1.48)	1.30(1.52)	46.67
		Above 16 (H_3)	1.47(1.57)	2.00(1.73)	2.10(1.76)	45.00
Sem±			0.07	0.59	0.17	5.36
CD(P=0.05)			NS	NS	0.15	1.87

Table 2: Effect of date of sowing, variety, head diameter and their interaction on total soluble solids (°B) of broccoli stored in room condition.

Date of sowing Variety Head diameter (cm)			**Days in storage**			
Effect of date of sowing			**At harvest**	**1**	**2**	**3**
15th Sept (D_1)			7.82	7.27	7.12	6.89
30th Sept (D_2)			7.88	7.78	7.64	7.01
15th Oct (D_3)			7.95	7.22	6.91	6.57
Sem±			0.06	0.03	0.07	0.04
CD(P=0.05)			0.17	NS	NS	0.11
Effect of variety						
Aishwarya (V_1)			7.78	7.57	7.31	6.95
Sadhana (V_2)			7.18	7.35	7.13	6.70
Sem±			0.06	0.04	0.06	0.03
CD(P=0.05)			0.17	0.11	NS	0.88
Effect of head diameter						
≥12<14(H_1)			7.82	7.41	7.09	6.73
≥14<16(H_2)			7.78	7.48	7.26	6.96
Above 16 (H_3)			7.70	7.27	7.32	6.79
Sem±			0.07	0.03	0.07	0.04
CD(P=0.05)			NS	NS	NS	0.11
Effect of interaction						
		≥12<14(H_1)	7.40	7.00	6.83	6.83
15th Sept (D_1)	Aishwarya (V_1)	≥14<16(H_2)	7.47	6.80	7.17	6.80
		Above 16 (H_3)	7.93	7.50	7.03	7.00
		≥12<14(H_1)	7.47	7.10	7.07	6.93
15th Sept (D_1)	Sadhana (V_2)	≥14<16(H_2)	7.17	7.17	6.83	6.77
		Above 16 (H_3)	7.53	6.93	7.23	6.93
		≥12<14(H_1)	8.63	8.63	7.63	7.00
30th Sept (D_2)	Aishwarya (V_1)	≥14<16(H_2)	8.97	8.97	8.03	7.07
		Above 16 (H_3)	9.00	9.00	8.03	6.97
		≥12<14(H_1)	7.93	7.63	7.00	6.93
30th Sept (D_2)	Sadhana (V_2)	≥14<16(H_2)	7.90	7.67	7.67	7.07
		Above 16 (H_3)	8.00	7.70	7.50	7.03
		≥12<14(H_1)	8.03	7.23	6.97	6.33
15th Oct (D_3)	Aishwarya (V_1)	≥14<16(H_2)	7.83	7.27	6.77	6.27
		Above 16 (H_3)	7.83	7.30	6.70	6.06
		≥12<14(H_1)	7.47	7.17	6.87	6.33
15th Oct (D_3)	Sadhana (V_2)	≥14<16(H_2)	7.40	7.73	7.17	7.17
		Above 16 (H_3)	7.40	7.23	6.97	6.73
Sem±			0.16	0.10	0.18	0.10
CD(P=0.05)			NS	NS	0.54	0.30

Table 3: Effect of date of sowing, variety, head diameter and their interaction on ascorbic acid content (mg/100g) of broccoli stored in room condition.

Date of sowing Variety Head diameter (cm)			Days in storage			
Effect of date of sowing			**At harvest**	**1**	**2**	**3**
15th Sept (D_1)			139.94	115.15	95.72	64.00
30th Sept (D_2)			136.33	119.17	106.89	91.78
15th Oct (D_3)			131.29	119.17	101.06	84.89
S.Em±			0.94	1.27	1.10	1.78
CD(P=0.05)			N.S	N.S.	3.20	5.11
Effect of variety						
Aishwarya (V_1)			138.37	116.10	103.96	83.67
Sadhana (V_2)			133.33	119.56	98.48	76.78
S.Em±			0.77	1.27	0.83	1.45
CD(P=0.05)			2.219	2.99	2.61	4.17
Effect of head diameter						
≥12<14(H_1)			136.11	121.933	104.78	84.33
≥14<16(H_2)			135.67	118.56	106.61	86.14
Above 16 (H_3)			135.28	113.00	92.28	70.19
S.Em±			0.94	1.27	1.10	1.78
CD(P=0.05)			N.S	3.66	3.19	5.11
Effect of interaction						
		≥12<14(H_1)	142.33	118.26	100.00	72.33
15th Sept (D_1)	Aishwarya (V_1)	≥14<16(H_2)	142.66	110.00	97.00	64.67
		Above 16 (H_3)	142.33	105.00	93.33	56.33
		≥12<14(H_1)	138.33	115.00	95.33	63.67
15th Sept (D_1)	Sadhana (V_2)	≥14<16(H_2)	139.00	116.33	96.67	68.33
		Above 16 (H_3)	135.00	117.66	92.00	58.66
		≥12<14(H_1)	139.00	116.33	113.33	104.33
30th Sept (D_2)	Aishwarya (V_1)	≥14<16(H_2)	136.00	116.33	112.33	91.66
		Above 16 (H_3)	136.66	100.00	82.67	66.00
		≥12<14(H_1)	139.33	139.33	112.33	99.00
30th Sept (D_2)	Sadhana (V_2)	≥14<16(H_2)	132.33	122.33	120.67	110.66
		Above 16 (H_3)	134.66	120.66	100.00	79.00
		≥12<14(H_1)	135.00	122.00	117.66	102.33
15th Oct (D_3)	Aishwarya (V_1)	≥14<16(H_2)	135.00	127.33	118.67	102.66
		Above 16 (H_3)	136.33	121.00	100.67	92.66
		≥12<14(H_1)	125.67	120.67	90.00	64.33
15th Oct (D_3)	Sadhana (V_2)	≥14<16(H_2)	129.33	119.00	94.33	78.83
		Above 16 (H_3)	126.67	113.67	85.00	68.50
S.Em±			2.31	3.09	2.72	4.35
CD(P=0.05)			NS	8.96	NS	NS

Table 4: Effect of date of sowing, variety, head diameter and their interaction effect on chlorophyll content (µg/g) of broccoli stored in room condition.

Date of sowing Variety Head diameter(cm)			Days in storage			
Effect of date of sowing			**At harvest**	**1**	**2**	**3**
15th Sept (D_1)			297.00	273.00	219.56	181.00
30th Sept (D_2)			315.89	278.56	238.78	192.00
15th Oct (D_3)			299	286.22	261.17	186.64
S.Em±			0.98	0.70	1.35	3.28
CD(P=0.05)			NS	2.04	NS	9.44
Effect of variety						
Aishwarya (V_1)			307.89	276.60	208.63	174.67
Sadhana (V_2)			300.40	281.93	271.04	198.43
Sem±			0.80	0.57	1.10	2.68
CD(P=0.05)			2.32	1.67	3.17	7.71
≥12<14(H_1)			303.40	288.94	251.78	195.51
≥14<16(H_2)			304.57	278.17	240.22	191.36
Above 16 (H_3)			304.48	270.67	227.50	172.78
Sem±			0.98	0.40	1.35	3.28
CD(P=0.05)			NS	2.04	3.89	9.44
Effect of interaction						
		≥12<14(H_1)	292.33	296.00	214.00	170.00
15th Sept (D_1)	Aishwarya (V_1)	≥14<16(H_2)	293.00	280.66	197.00	171.66
		Above 16 (H_3)	292.33	272.00	175.00	133.66
		≥12<14(H_1)	299.66	291.66	272.00	227.66
15th Sept (D_1)	Sadhana (V_2)	≥14<16(H_2)	302.33	257.66	234.33	198.66
		Above 16 (H_3)	302.33	251.33	225.00	184.33

		≥12<14(H_1)	330.73	277.33	201.00	191.33
30th Sept (D_2)	Aishwarya (V_1)	≥14<16(H_2)	331.76	269.33	199.33	186.66
		Above 16 (H_3)	330.53	262.66	198.66	184.00
		≥12<14(H_1)	299.00	291.66	288.00	225.00
30th Sept (D_2)	Sadhana (V_2)	≥14<16(H_2)	301.00	287.33	282.00	177.33
		Above 16 (H_3)	302.33	283.00	263.66	187.66
		≥12<14(H_1)	300.33	280.33	243.33	172.33
15th Oct (D_3)	Aishwarya (V_1)	≥14<16(H_2)	301.00	277.33	234.33	201.00
		Above 16 (H_3)	299.00	262.33	215.00	161.33
		≥12<14(H_1)	298.33	296.66	292.33	186.70
15th Oct (D_3)	Sadhana (V_2)	≥14<16(H_2)	298.33	296.66	294.33	212.83
		Above 16 (H_3)	300.33	292.66	287.66	185.66
Sem±			2.42	1.74	3.31	8.06
CD(P=0.05)			NS	5.00	9.515	NS

Table 5: Effect of date of sowing, variety, head diameter and their interaction effect on yellowing (%) of broccoli stored in room condition. (*Values in brackets are angular transformed data)

Date of sowing Variety Head diameter (cm)			Days in storage		
Effect of date of sowing			**1**	**2**	**3**
15th Sept (D_1)			3.25 (8.77)	17.72(22.14)	40.28(38.28)
30th Sept (D_2)			6.12(13.89)	50.06(43.35)	90.60(71.88)
15th Oct (D_3)			13.21(21.33)	59.83(37.05)	92.32(72.17)
S.Em±			0.51	0.40	2.06
CD(P=0.05)			1.47	1.46	1.30
Effect of variety					
Aishwarya (V_1)			8.32(17.11)	74.63(62.79)	93.13(73.36)
Sadhana (V_2)			6.73(15.47)	10.44(18.44)	55.67(47.15)
S.Em±			0.41	0.33	1.68
CD(P=0.05)			1.19	1.19	1.06
Effect of head diameter					
≥12<14(H_1)			2.87(9.12)	34.72(52.34)	68.07(51.14)
≥14<16(H_2)			7.38(15.98)	37.33(54.95)	73.24(55.41)
Above 16 (H_3)			12.33(20.14)	55.56(47.60)	81.89(60.12)
S.Em±			0.51	0.40	2.06
CD(P=0.05)			1.46	1.46	1.30
Effect of interaction					
		≥12<14(H_1)	1.33(6.53)	90.00(71.55)	99.00(85.35)
15th Sept (D_1)	Aishwarya (V_1)	≥14<16(H_2)	6.00(14.14)	89.33(70.92)	99.60(87.21)
		Above 16 (H_3)	8.00(16.42)	95.66(78.03)	99.33(86.15)
		≥12<14(H_1)	2.33(8.74)	11.66(19.87)	66.66(54.76)
15th Sept (D_1)	Sadhana (V_2)	≥14<16(H_2)	6.00(14.14)	89.33(70.92)	99.60(87.21)
		Above 16 (H_3)	9.33(17.75)	43.33(41.13)	96.00(78.64)
		≥12<14(H_1)	0.33(1.91)	97.00(80.08)	99.43(85.85)
30th Sept (D_2)	Aishwarya (V_1)	≥14<16(H_2)	2.33(8.74)	95.66(77.97)	99.50(86.71)
		Above 16 (H_3)	2.66(7.63)	97.667(81.22)	99.66(88.08)
		≥12<14(H_1)	0.00	0.00	50.00(44.98)
30th Sept (D_2)	Sadhana (V_2)	≥14<16(H_2)	0.00	0.00	97.00(80.24)
		Above 16 (H_3)	10.00(18.42)	10.00(18.42)	98.00(81.84)
		≥12<14(H_1)	0.00(0.00)	9.67(18.10)	93.33(75.21)
15th Oct (D_3)	Aishwarya (V_1)	≥14<16(H_2)	1.00(5.73)	10.00(18.42)	50.00(44.98)
		Above 16 (H_3)	6.00(13.77)	86.66(68.82)	98.33(85.68)
		≥12<14(H_1)	0.00	0.00	0.00
15th Oct (D_3)	Sadhana (V_2)	≥14<16(H_2)	0.00	0.00	0.00
		Above 16 (H_3)	0.00	0.00	0.00
Sem±			1.24	1.00	1.74
CD(P=0.05)			3.52	2.88	5.00

Conclusion

It is very difficult to control the rapid senescence of young broccoli although reduction in wilting had been controlled with the use of packaging material in all the treatments. After critical analysis of the physiochemical changes occurring during the storage period of broccoli harvested at different head diameter for two different varieties sown at different dates it was found that small size broccoli sown at 15th September in variety Sadhana gave the least physiological loss in weight with least yellowing at the end of the 3 days storage period which corresponds to the higher marketability of the crop as well as high chlorophyll content. So sowing of broccoli earlier harvesting at small head size proved beneficial in extending better post harvest life during storage.

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