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Preharvest fruit bagging time regulates postharvest quality and shelf life of dragon fruit (*Hylocereus* spp.)

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ABSTRACT

Appropriate bagging time is imperative for effective use of fruit bagging technology in safe fruit production. A study was conducted at the Germplasm Centre of Bangladesh Agricultural University (BAU-GPC), Mymensingh during May 2018 to September 2019 with a view to determining the effect of preharvest fruit bagging time on postharvest qualities and shelf life of dragon fruit. The two-factor experiment was comprised of two varieties viz., BAU dragon fruit-1; BAU dragon fruit-2 and three bagging time viz., Fruit bagging at 7, 12 and 17 days after fruit setting (DAFS). The experiment was laid out in randomized complete block design with three replications. Black polythene bag was used as bagging material for this study. It was observed that fruit bagging at 7 DAFS significantly increased fruit length (11.74 cm), flesh weight (188.59 g), moisture content (85.06%), total soluble solids (14.79^{0}Brix) and shortened the maturity time (21.66 days) of BAU dragon fruit-1. Besides, fruit bagging at 7 DAFS significantly increased fruit diameter (7.60 cm), edible rate (74.29%), pH (4.72), dry matter content (20.59%), shelf life (11.65 days) and reduced peel weight (62.57 g), peel thickness (0.22 cm) of BAU dragon fruit-2. From the findings of this study it can be concluded that fruit bagging at 7 days after fruit setting resulted the improve the postharvest quality and shelf life of dragon fruit.

Keywords: Dragon fruit, dry matter content, flesh-peel ratio, peel thickness, pH, TSS

INTRODUCTION

Dragon fruit (*Hylocereus* spp.) is considered as one of the most beautiful fruits of the Cactaceae family with its light red skin stubbed with green scales and white, pink as well as red flesh with tiny black seeds. Dragon fruit is a sprawling or vine, terrestrial or epiphytic cactus which has received worldwide recognition, first as an ornamental plant and then a fruit crop. It is a long day plant with beautiful night blooming flower that is nick named as Nobel women, Queen of the night or the moonflower (Nandi *et al*., 2019). The creamy pulp with edible seeds has a very delicate aroma. The edible black seed of dragon fruit is a good source of omega-3, omega-6 fatty acids, polyunsaturated fats which are healthy fatty acids (Sinha *et al*., 2018). Dragon fruit is one of the most nutritious fruits that increase the digesting power. Besides, it has many medicinal and therapeutic properties as like blood fruit (Kalkame *et al*., 2018) which includes ability to control obesity, cancer, diabetes, high cholesterol as well as high blood pressure as like. Currently, it has been cultivated in many districts of Bangladesh especially, Natore, Pabna, Mymensingh, Gazipur, Munshiganj, Magura and at different Horticulture Centers under the Department of Agricultural Extension (DAE).

Although dragon fruit is heat loving, it can be damaged by long periods of intense sun and heat, resulting in sunscald. Bagging is the best option for protecting dragon fruit from sunburn and fruit cracking. Dragon fruit may also attract ants, beetles and fruit flies. These insects can also hamper the production of this fruit. Dragon fruits are also damaged by birds severely when it's getting mature. Due to various fungi, insects and birds attack, the superior fruit size as well as skin color is not possible get to properly thus infested fruits are not generally sold in the market.

Bagging is a physical protection technique, commonly applied to many fruits, which not only improves their visual quality by promoting peel coloration and reducing the incidence of fruit cracking and rusting, but can also change the micro environment for fruit development, which can have multiple effects on internal fruit quality (Son and Lee, 2008). Bagging has been extensively used in several fruits crops to improve skin color, reduce

the incidence of disease, insect pests, mechanical damage, sunburn of the skin and bird damage and to increase market value.

Due to its many beneficial effects, fruit bagging has become an integral part of different fruits cultivation in many countries of the world. Now-a-days, fruit bagging has been an eco-friendly practice in many kind of fruit such as mango (Hossain *et al.,* 2020), guava (Rahman *et al.,* 2018), banana (Rubel *et al.,* 2019), papaya, citrus, grape etc. However, very limited information has been found on the effect of fruit bagging time of dragon fruit in Bangladesh. Therefore, this experiment was undertaken to find out an optimum bagging time for dragon fruit production in Bangladesh which will ensure postharvest quality and enhance the shelf life of dragon fruit.

MATERIALS AND METHODS

The experiment was conducted at Bangladesh Agricultural University Germplasm Centre (BAU-GPC), Mymensingh, during May 2018 to September 2019. The experimental site was located between 24.43°N latitude, 90.25°E longitude and 18m altitude from the sea level. The soil of the experimental area was sandy loam type and belonging to the old Brahmaputra Flood Plain Alluvial Tract of AEZ 9 having non calcareous dark grey flood plain soil. The selected area was a medium high land. It was fertile and well drained and slightly acidic with p^H varying from 5.4 to 6.7. During the study period, the average maximum and minimum temperature were 34.01^{0}C and 25.30^{0}C, respectively. While the average relative humidity was 85.61%.

The two-factor experiment was conducted following Randomized Complete Block Design (RCBD) with three replications. The experimental treatments were two varieties of Dragon fruit *viz.,* V_1: BAU dragon fruit-1 (White flesh) and V_2: BAU dragon fruit-2 (Red flesh), and three bagging time *viz.,* T_1: Fruit bagging at 7 days after fruit setting (DAFS), T_2: Fruit bagging at 12 DAFS and T_3: Fruit bagging at 17 DAFS.

Regular observation during flowering time was continued to find out fruit setting time after anthesis and fruits were tagged for recording days after fruit setting. Black polythene bag was used for bagging of selected fruits in the month of May, 2019. The fruits were wrapped by black polythene bag at 7, 12 and 17 days after fruit setting. A small portion of two corners of each bag was cut off in order to prevent water deposition inside the bag. The bags were tightly tied with the help of rope so that water and insect-pest could not enter into the bag. Fruits were harvested at full mature stage, a common index of maturity is skin color change to almost full red (Nerd *et al.,* 1999). Five fruits were randomly selected from each replication of each treatment and counted days required to maturity (days). Fresh weight was recorded immediately after harvesting of fruits thereafter fruit length and diameter were measured using digital slide calipers. Fruit peel and flesh were separated carefully and recorded the weight for calculation of flesh-peel ratio and % edible rate. The peel thickness was measured by using digital slide calipers.

Determination of moisture and dry matter content

Fifty grams (50g) of fresh fruit sample of each treatment was taken and cut into small pieces on an aluminum foil and oven dried at 70^{0}C until the constant weight was attained. Percent moisture content was calculated according to the following formula:

$$\% \text{ moisture content} = \frac{\text{Fresh weight of sample(g)} - \text{dry weight of sample(g)}}{\text{Fresh weight of sample(g)}} \times 100$$

% dry matter content was calculated as % dry matter content =100 - %moisture content

Determination of fruit pH

The pH of dragon fruit was recorded by using an electric pH meter. The pH meter was standardized using buffer solutions described by Ranganna (1994). Samples of 10 g fresh pulp was homogenized in 10 ml de-ionized water pH 7.0 and the flesh of homogenate was measured with the pH meter.

Determination of Total Soluble Solids (^{0}Brix)

Total soluble solids (TSS) content of dragon fruit was estimated using digital refractometer (Model N-1 á, Atago Company Ltd., Japan). A drop of juice

was squeezed from the dragon fruit flesh and taken on the prism of refractometer. TSS content was recorded from the direct reading of the instrument. Temperature correction was made using the temperature correction chart.

Shelf life (days)

Five fruits of each variety and treatment were stored in an ambient condition (30±2^{0}C) to observe the storage life. Fruits were monitored regularly and the shelf life of fruits was counted from the date of harvesting to the last edible stage.

Statistical analysis

The collected data on various parameters were statistically analyzed using MSTATC statistical package program. The means for all the treatments were calculated and analysis of variances (ANOVA) for all the parameters was compared by least significant difference (LSD) test at 5% and 1% levels of probability (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Effect of variety on fruit maturity time and morphological traits of dragon fruit

Fruit growth, other developmental traits and time to fruit maturity were impacted differently due to variety during the study period. It was observed that no significant difference found on days to maturity and fruit flesh weight (Table 1) while other studied parameters significantly influenced by fruit variety. In respect of fruit fresh weight, length and peel weight, significant variations were observed between two varieties. The higher fruit fresh weight (246.92 g), length 10.80 cm) and peel weight (86.79 g) were recorded from BAU dragon fruit-1,while BAU dragon fruit-2 produced the lower fruit fresh weight (237.59 g), length (9.01 cm) and peel weight (76.80 g) (Table 1). Similarly, fruit diameter and peel thickness also influenced by the fruit variety. The higher fruit diameter (6.81 cm) and peel thickness (0.36 cm) were recorded from BAU dragon fruit-2, while BAU dragon fruit-1 produced lower fruit diameter (6.53 cm) and peel thickness (0.26cm) (Table 1). The findings of this research are corroborated with the results of Chowdhury *et al.* (2020). They noticed that white fleshed BAU dragon fruit-1 performed superior in terms of fruit length, fresh and peel weight. Similar results were reported by Mallik *et al.* (2018) in white flesh dragon fruit.

Fruit qualitative traits were also influenced by variety. It was found that BAU dragon fruit-2 produced maximum flesh-peel ration (2.15), edible rate (66.84%), dry matter content (17.80%), fruit pH (4.65), TSS (12.79%) and shelf life (9.99 days), while BAU dragon fruit-1 contained highest moisture (85.01%), lowest pH (4.48), TSS (12.41%) and shelf life (9.68 days) (Table 2). Significant variations were noticed on morphological and nutritional traits of two varieties of dragon fruit (Mallik *et al.,* 2018).

Table 1: Effect of variety on days to fruit maturity and morphological traits of dragon fruit

Variety	Days to maturity	Fruit fresh weight (g)	Fruit length (cm)	Fruit diameter (cm)	Flesh weight (g)	Peel weight (g)	Peel thickness (cm)
V_1 (BAU dragon fruit-1)	25.16	246.92	10.80	6.53	159.50	86.79	0.26
V_2 (BAU dragon fruit-2)	24.91	237.59	9.01	6.81	160.15	76.80	0.36
$LSD_{(0.05)}$	0.59	1.27	0.19	0.09	0.94	0.76	0.02
Level of significance	NS	**	**	**	NS	**	**

** indicates significant at 1% level of probability, NS: Non-significant

Effect of bagging time on fruit maturity time and morphological traits of dragon fruit

Fruit bagging time significantly influenced on days required to fruit mature as well as other fruit growth parameters. It was found that fruit bagging at 17 DAFS took the longest time to mature (27.16 days) and the earliest fruit maturity achieved (21.3 days) when fruits were bagged at 7 DAFS (Table 3). The highest fruit fresh weight, longest fruit length, diameter and flesh weight (258.3 g, 11.06 cm, 7.57 cm and 185.63 g, respectively) were obtained from fruits bagging at 7 DAFS and the

Table 2: Effect of variety on flesh-peel ratio, edible rate, moisture content, dry matter content, pH, TSS and shelf life of dragon fruit

Variety	Flesh-peel ratio	Edible rate (%)	Moisture content (%)	Dry matter content (%)	pH	TSS (^{0}Brix)	Shelf life (days)
V_1 (BAU dragon fruit-1)	1.85	64.33	85.01	14.98	4.48	12.41	9.68
V_2 (BAU dragon fruit-2)	2.15	66.84	82.19	17.8	4.65	12.79	9.99
$LSD_{(0.05)}$	0.02	0.23	0.37	0.37	0.05	0.13	0.16
Level of significance	**	**	**	**	**	**	**

** indicates significant at 1% level of probability

lowest fruit fresh weight, fruit length, diameter and flesh weight (240.66 g, 9.55 cm, 6.72cm and 160.52 g, respectively) noticed from fruits bagging at 17 DAFS (Table 3). Costa *et al.* (2017) reported that bagging does not alter the physical and chemical traits of red pitaya. Fruit bagging with different materials did not alter fruit length, diameter, fresh weight and pulp yield of atemoya and sugar apple (Pereira *et al.,* 2009), while Santos *et al.* (2007) achieved higher fresh weight of apple cv. Fiju Suprema from waxed paper bagged fruits.

On the contrarily, early fruit bagging reduced peel weight and thickness resulting the minimum peel weight and thickness (72.04 g and 0.25 cm) obtained from the fruits bagging at 7 DAFS while the maximum peel weight and thickness (85.02 g and 0.31cm) attained from bagging at 12 DAFS (Table 3).

Table 3: Effect of bagging time on days to fruit maturity and morphological traits of dragon fruit

Treatment	Days to maturity	Fruit fresh weight (g)	Fruit length (cm)	Fruit diameter (cm)	Flesh weight (g)	Peel weight (g)	Peel thickness (cm)
T_1 (Bagging at 7 DAFS)	21.83	258.3	11.06	7.57	185.63	72.04	0.25
T_2 (Bagging at 12 DAFS)	24.66	257.29	10.32	7.10	171.64	85.02	0.31
T_3 (Bagging at 17 DAFS)	27.16	240.66	9.55	6.72	160.52	79.50	0.27
$LSD_{(0.05)}$	0.84	1.79	0.27	0.13	1.32	1.08	0.03
Level of significance	**	**	**	**	**	**	**

** indicates significant at 1% level of probability

As fruit flesh weight, peel thickness and peel weight were impacted by fruit bagging time therefore, flesh-peel ratio, percent edible rate and quality of dragon fruit were also affected by the time of bagging. The maximum flesh-peel ratio, edible rate, dry matter content, pH and TSS (2.61, 71.97%, 17.76%, 4.70, 14.34^{0}Brix) obtained from fruits bagging at 7 DAFS and the minimum results recorded from 12 and 17 DAFS (Table 4). Early bagging may increase fruit edible rate as the insect pest infestation remains minimum during that time which was supported by Tran *et al.* (2015). Bagging fruits after 7 days anthesis enhanced % TSS of dragon fruits (Tuan *et al.,* 2017). They stated that about 15% TSS increased due to earlier bagging. In this study we found about 29% improvement of TSS bagging at 7 DAFS. Bentley *et al.* (1992) claimed that sweetness in apple fruit was remarkably enhanced by fruit bagging at the golf-ball size of fruit development.

However, fruit bagging at 17 DAFS contained the highest moisture content (83.36%) but shelf life was the lowest (9.92 days) as compared to other bagging time. The longest shelf life of fruits noticed from fruits bagging at 7DAFS (11.25 days) which had lowest moisture content (82.23%)(Table 4). Fruit bagging effectively protect fruits from any physical injuries, diseases pest attack, bird attack, sunburn and other environmental hazards as a results shelf life of harvested fruits were longer shelf life as compared to non-bag fruits (Huixae, 2010; Hossain *et al.,* 2020). In this study, it was noticed that dragon fruit bagged at 7 DAFS prolonged shelf life as compared to fruit bagging at later stage.

Table 4: Effect of bagging time on flesh-peel ratio, edible rate, moisture content, dry matter content, pH, TSS and shelf life of dragon fruit

Treatment	Flesh-peel ratio	Edible rate (%)	Moisture content (%)	Dry matter content (%)	pH	TSS (Brix)	Shelf life (days)
T_1 (Bagging at 7 DAFS)	2.61	71.97	82.23	17.76	4.70	14.34	11.25
T_2 (Bagging at 12 DAFS)	2.02	66.69	83.05	16.94	4.63	12.47	10.58
T_3 (Bagging at 17 DAFS)	2.03	66.66	83.36	16.64	4.50	11.45	9.92
$LSD_{(0.05)}$	0.03	0.23	0.52	0.52	0.07	0.18	0.23
Level of significance	**	**	**	**	**	**	**

** indicates significant at 1% level of probability

Combined effects of variety and bagging time on days to fruit maturity and morphological traits of dragon fruit

The combined effect of variety and bagging time had significant impact on days to fruit maturity, and other morphological traits and shelf life of dragon fruit. The shortest days to maturity (21.66 days) was found when BAU dragon fruit-1 bagged at 7 DAFS and the longest days to maturity (27.33 days) recorded from BAU dragon fruit-2 bagged at 17 DAFS (Table 5). The highest fruit fresh weight and flesh weight (270.72 g and 188.59 g) were found when BAU dragon fruit-1 bagged at 7 DAFS. The lowest values of those traits (236.57 g and 152.50 cm) obtained from BAU dragon fruit-1 with bagging at 17 DAFS (Fig. 1, Table 5). In carambola, fruit bagging with plastic bag at 10 days after full bloom increased fruit weight (Xu *et al.,* 2008). Marble stage reported as a proper bagging time for mango cv. Alphonso (Haldankar *et al.,* 2015). In other variety of mango (cv. Langra) proper bagging time was reported 40-45 days after fruit setting (Islam *et al.,* 2019) and cv. Amrapali 30-45 days after fruit setting (Hossain *et al.,* 2020).

The highest fruit length(11.74 cm) was obtained when BAU dragon fruit-1 bagged at 7 DAFS and the lowest fruit length (8.40 cm) achieved from the combination of BAU dragon fruit-2 bagged at 17 DAFS but fruit diameter was maximum (7.60 cm) in BAU dragon fruit-2 bagged at 7 DAFS (Table 5).

It was also observed that peel weight, thickness and flesh-peel ratio of dragon fruit significantly influenced due to the combined effect of variety and bagging time. The lowest peel weight (62.57 g) and peel thickness (0.22 cm) obtained from BAU dragon fruit-2 bagged at 7 DAFS and the highest peel weight (88.53 g) was found when BAU dragon fruit-1 bagged at 12 DAFS. Similarly, the maximum peel thickness (0.39 cm) was found when BAU dragon fruit-2 bagged at 12 DAFS (Table 5).

The highest flesh-peel ratio (2.92) was found from BAU dragon fruit-2 bagged at 7 DAFS (V2T1) and the lowest result (1.83) obtained from the combination of BAU dragon fruit-1 and 17 DAFS (V1T3) (Fig. 2). It was also observed that the highest edible rate (74.29%) recorded when BAU dragon fruit-2 bagged at 7 DAFS while the lowest edible rate (64.46%)obtained from BAU dragon fruit-1 under bagged at 17 DAFS (Table 6). Early bagging may increase fruit edible rate as the insect pest infestation remains minimum during that time which was supported by Tran *et al.* (2015).

At the same time the highest fruit moisture content (85.06%) obtained when BAU dragon fruit-1 was bagged at 7 DAFS and the lowest value (79.40%) was achieved from the combination of BAU dragon fruit-2 and 7 DAFS (Table 6).

Fruit pH value and dry matter content also influenced by the combined effects of variety and fruit bagging time. The highest pH (4.72), and dry matter content (20.59%) was found from the combination of BAU dragon fruit-2 and 7 DAFS (V_2T_1) (Table 5, Fig. 3). The lowest pH (4.38) was achieved from the combination of BAU dragon fruit-1 with 17 DAFS (Table 6). While the lowest dry matter content (14.93%) was noticed from the combination of BAU dragon fruit-1 with 7 DAFS (V_1T_1) (Fig.3).

Table 5: Combined effects of variety and bagging time on days to fruit maturity and morphological traits of dragon fruit

Treatment	Combinations	Days to maturity	Fruit length (cm)	Fruit diameter (cm)	Flesh weight (g)	Peel weight (g)	Peel thickness (cm)
V_1(BAU dragon fruit-1)	Bagging at 7 DAFS	21.66	11.74	7.54	188.59	81.50	0.28
	Bagging at 12 DAFS	24.66	11.40	6.79	165.40	88.53	0.24
	Bagging at 17 DAFS	27.00	10.69	6.41	152.50	83.43	0.22
V_2 (BAU dragon fruit-2)	Bagging at 7 DAFS	22.00	10.37	7.60	182.66	62.57	0.22
	Bagging at 12 DAFS	24.66	9.24	7.41	177.87	81.50	0.39
	Bagging at 17 DAFS	27.33	8.40	7.03	168.54	75.57	0.32
$LSD_{(0.05)}$		1.19	0.39	0.19	1.87	1.52	0.04
Level of significance		**	**	**	**	**	**

** indicates significant at 1% level of probability

Table 6: Combined effect of variety and bagging time on edible rate, moisture content, pH, TSS and shelf lifeof dragon fruit

Treatment	Combinations	Edible rate (%)	Moisture content (%)	pH	TSS (^{0}Brix)	Shelf life (days)
V_1(BAU dragon fruit-1)	Bagging at 7 DAFS	69.66	85.06	4.68	14.79	10.84
	Bagging at 12 DAFS	64.97	83.99	4.58	12.19	9.96
	Bagging at 17 DAFS	64.46	84.58	4.38	10.41	9.85
V_2(BAU dragon fruit-2)	Bagging at 7 DAFS	74.29	79.40	4.72	13.90	11.65
	Bagging at 12 DAFS	68.41	82.10	4.68	12.74	11.21
	Bagging at 17 DAFS	68.86	82.14	4.62	12.49	10.00
$LSD_{(0.05)}$		0.46	0.74	0.09	0.26	0.33
Level of significance		**	**	**	**	**

** indicates significant at 1% level of probability

However, the highest TSS (14.79 Brix) was found when BAU dragon fruit-1 bagged at 7 DAFS and the lowest TSS (10.41 Brix) achieved from the combination of BAU dragon fruit-1 and 17 DAFS (Table 6). The longest shelf life (11.65 days) was obtained from BAU dragon fruit-2 with bagging at 7 DAFS and the shortest shelf life (9.85days) recorded when BAU dragon fruit-1 bagged at 17 DAFS (Table 6).

However, the highest TSS (14.79%) was found when BAU dragon fruit-1 bagged at 7 DAFS and the lowest TSS (10.41%) achieved from the combination of BAU dragon fruit-1 and 17 DAFS (Table 6). Bentley *et al*. (1992) noticed that sweetness in apple fruit was significantly improved due to bagging at the golf-ball size of fruit development. The longest shelf life (11.65 days) was obtained from BAU dragon fruit-2 with bagging at 7 DAFS and the shortest shelf life (9.85days) recorded when BAU dragon fruit-1 bagged at 17 DAFS (Table 6). Chowdhury *et al* (2020) reported that fruit bagging with black polythene bag extended shelf life of dragon fruit as it protects fruits from all insect pests infestation and maintained microenvironment of the fruit. Fruit bagging at 7 DAFS greatly enhanced fruit maturity,

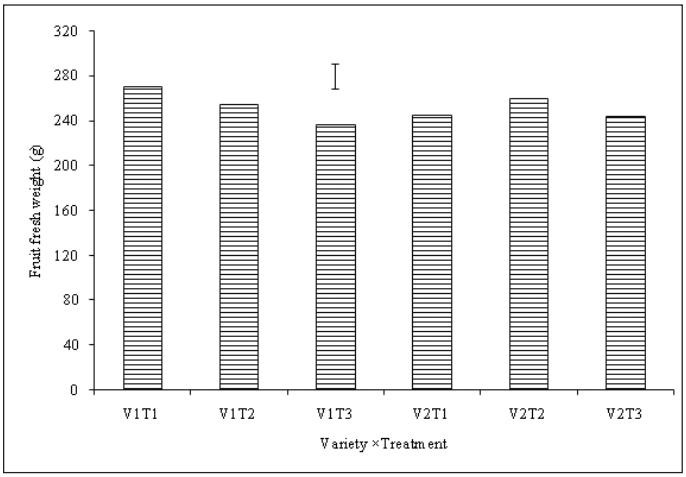

Fig. 1: Combined effect of variety and treatment on fruit fresh weight of dragon fruit. Bar indicates LSD at 1% level of probability. V_1: BAU dragon fruit-1, V_2: BAU dragon fruit-2, T_1: Bagging at 7 DAFS, T_2: Bagging at 12 DAFS, T_3: Bagging at 17 DAFS.

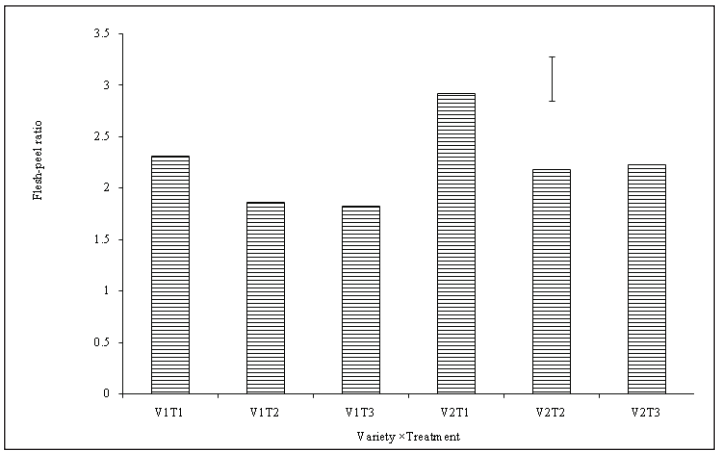

Fig. 2: Combined effect of variety and treatment on flesh-peel ratio of dragon fruit. Bar indicates LSD at 1% level of probability. V_1: BAU dragon fruit-1, V_2: BAU dragon fruit-2, T_1: Bagging at 7 DAFS, T_2: Bagging at 12 DAFS, T_3: Bagging at 17 DAFS.

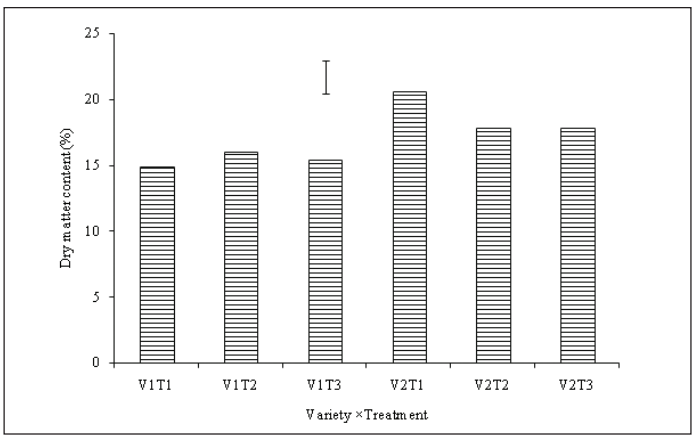

Fig. 3: Combined effect of variety and treatment on dry mater content of dragon fruit. Bar indicates LSD at 1% level of probability. V_1: BAU dragon fruit-1, V_2: BAU dragon fruit-2, T_1: Bagging at 7 DAFS, T_2: Bagging at 12 DAFS, T_3: Bagging at 17 DAFS.

fruit weight, flesh weight, edible rate and remarkably reduced peel thickness and increased flesh-peel ration. These findings are in agreement with the results of Tuan *et al.* (2017). They stated that bagging fruits after 7 days anthesis produced highest fresh weight, edible rate as compared to bagging after 15 days anthesis as well as non-bagged fruits.

CONCLUSION

Considering the findings of this experiment, it can be concluded that both the varieties showed better results in terms of fruit quality and shelf life while fruit bagging at 7 days after fruit setting. Fruit bagging with black polythene bag promoted almost all the morphological traits of fruit as well as days required to maturity, total dry weight, dry matter content, TSS, pH and shelf life of dragon fruit. It can be summarized that fruit bagging at 7 days after fruit setting with black polythene bag could be an effective eco-friendly technology to produce quality dragon fruit with longer postharvest storage life.

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