Project ID 538

Competitive Research Grant

Sub-Project Completion Report

on

Development of production package with special emphasis on off season flowering of dragon fruit Implementing organization: Bangladesh Agricultural Research Institute

Project Duration

July 2017 to September 2018

Regional Horticulture Research Station
Bangladesh Agricultural Research Institute
Shibpur, Narsingdi

Submitted to
Project Implementation Unit-BARC, NATP-2
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Development of production package with special emphasis on off season flowering of dragon fruit

Project Implementation Unit
National Agricultural Technology Program-Phase II Project (NATP-2)
Bangladesh Agricultural Research Council (BARC)
New Airport Road, Farmgate, Dhaka – 1215
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Acronyms

µg	:	Microgram
BADC	:	Bangladesh Agricultural Development Corporation
*C**	:	Chroma
CFL	:	Compact Fluorescent Lamp
CV	:	Coefficient of Variation
DAA	:	Days After Anthesis
DAC	:	Days After Cutting
DAE	:	Department of Agricultural Extension
FYM	:	Farm Yard Manure
h°	:	Hue angle
KGF	:	Krishi Gobeshona Foundation
kgf cm^{-2}	:	Kilogram-force per Square Centimeter
*L**	:	Lightness
LED	:	Light Emitting Diodes
Meq	:	Milli-equivalents
MoP	:	Muriate of Potash
MSTAT-C	:	Statistical software developed by Michigan State University
NGO	:	Non-Government Organization
ppm	:	Parts Per Million
RHRS		Regional Horticultural Research Station
TSP	:	Triple Super Phosphate
TSS	:	Total Soluble Solids
WHO	:	World Health Organization
ZnSO4	:	Zinc Sulphate

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Executive Summary

Dragon fruit (*Hylocereus undatus*) is a newly introduced exotic fruit of Bangladesh. Dragon fruit is one of the most widely grown fruit crop suitable for grown in sandy loam to clay soil under temperature between 20-30º C. The interest on this fruit has emerged due to its agronomic, industrial, nutritional and medicinal importance and considered as fruit of future. Due to its high profitability, wide adaptability, low crop maintenance, uniqueness health benefits and shorter gestation period it could be a promising commercial crop of Bangladesh.

Dragon fruit is a perennial plant and starts fruiting in the second year, and continuous to grow for about 20 years. Under natural cultivation conditions, it has been considered as a long-day plant which produces fruits under long day length or when dark periods (nights) are reduced below the threshold level. In different countries it produces fruits almost year-round by day-length enhancement or night-breaking by artificial lightening during the short-day period to induce flowering. The day length of Bangladesh during Sep to Apr is actually shorter to produce flowering of dragon fruit. If the day length of the period can be widened it will be possible to flower this crop and hence year-round fruiting of dragon fruit would successfully be done. Propagation of dragon fruit is generally done through seed and other vegetative means. But the easy way of multiplication is the vegetative propagation, by which the genetic purity can be maintained. But, success, survival and growth of cutting are dependent on a number of factors like variety, length, methods and time of cutting, time and age of stem and environmental conditions. Among the factors that influence the crop production, fertilizer is the most important one that plays a crucial role in yield increase. The natural soil fertility often thought to be enough for the nourishment of trees. But application of N, P and K per plant per year markedly increased the number of fruits/plant, yield and quality. Fruit harvest at proper maturity is the most important factor that determines postharvest life and quality of a commodity. Proper stage and size are not necessarily always related with physiological maturity, it may concern with commercial maturity to the crop, even to variety. Commercial maturity, in other words, horticultural maturity has mainly three aspects, consumers' preference, nutritional quality and growers and traders' interest.

Considering the above context, this project is undertaken to develop a production package of dragon fruit with special emphasis on off season production techniques, to standardize propagation techniques, fertilizer management and to determine the commercial maturity indices along with quality characteristics. With this context, number of experiments is executed in three locations viz. Shibpur, Narsingdi; Joydebpur, Gazipur and Raikhali, Rangamati to study the effect of day-length enhancement and night-breaking by artificial lightening on off season fruit production of dragon fruit. Effect of cutting length and time of cutting on the success and growth of dragon fruit propagation and to standardize the fertilizer dose and determination the commercial maturity of dragon fruit in Bangladesh has been finalized.

CRG Sub-Project Completion Report (PCR)

A. Sub-project Description

1. Title of the CRG sub-project: Development of production package with special emphasis on off season flowering of dragon fruit

2. Implementing organization: Bangladesh Agricultural Research Institute

3. Name and full address with phone, cell and E-mail of PI/Co-PI (s):

Dr. Md. Moshiur Rahman
Principal Scientific Officer
Regional Horticulture Research Station
BARI, Shibpur, Narsingdi
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4. **Sub-project budget (Tk):**

   4.1 Total: 17,70,000.00
   4.2 Revised (if any):

5. **Duration of the sub-project:**

   5.1 Start date (based on LoA signed): July 2017
   5.2 End date: 30 September 2018

6. **Justification of undertaking the sub-project:**
   Dragon fruit (*Hylocereus undatus*) is a climbing-vine-cactus belonging to the family Cactaceae. It is originated in Mexico, and Central and South America. Its interest has emerged due to agronomic, industrial, nutritional and medicinal importance, economic potential and currently being marketed worldwide, and considered as fruit of future. Dragon fruit is one of the most widely grown species and extensively adapted crop established in geographically diverse areas (*Pascua, et al.* 2010; 2013). It grows well in assorted types of soils from sandy loam to clay loam. The best soil for its cultivation is well drained loams with plenty of organic matter (*Gunesena and Pushpakumara*, 2006). Suitable temperature for dragon fruit cultivation is 20-30ºC. Considering this point, soil and climatic conditions of Bangladesh are suitable for its cultivation. Dragon fruit has been introduced to Bangladesh in recent decades and becoming a popular fruit crop within a short time. Due to its high profitability, wider adaptability, low crop maintenance, uniqueness health benefits and shorter gestation period it would be a promising commercial crop of Bangladesh.

Dragon fruit is a perennial plant and starts fruits in the second year, and attain in full production within five years after planting and continue to grow for about 20 years. Under natural cultivation conditions, it has been considered as a long-day plant which produces fruits under long day length or when dark periods (nights) are reduced below the threshold level. In different countries, dragon fruit plants produce fruits almost year round by providing additional lighting treatment during the short-day period to induce flowering at the required period (*Dinh-Ha et al.,* 2015). So, it is necessary to regulate flowering under shorter days using artificial lighting to produce fruit in off season.

In Bangladesh dragon fruit becomes available in May to September associated with most of the seasonal fruits. But it has potentiality to produce fruit in September to May by artificial lightening. According to World Health Organization (WHO), per capita requirement of fruits is 175 g but in Bangladesh its consumption is only 78 g, which is much below than the minimum requirement (Anon., 2011). On the other hand, from November to April most of the fruits are not available in this country. In several countries, flowering is induced during shorter days (November to April) using artificial lightening treatments (*Dinh-Ha et al.,* 2015). This lightening treatment may help to increase the availability of fruits in this lean period of Bangladesh. In this regard, day light prolongation or night breaking techniques with supplemental lighting methods may be helpful to regulate flowering to produce abundant or adequate fruit settings and also off season production in our country.

Beside this, as an exotic crop of Bangladesh, some factors such as seasonality, nutrient management, flowers drop due to rainfall, propagation, maturity, pests and disease management are deserved to study. With a view to develop of a production package of dragon fruit with special emphasis on year round production, the present study has been undertaken.

7. **Sub-project goal:** To increase availability of dragon fruit round the year

8. **Sub-project objective (s):**
    i. To develop off season production technique of dragon fruit
    ii. To standardize a production package of dragon fruit cultivation

9. **Implementing location (s):**
Shibpur, Narsingdi; Joydebpur, Gazipur and Raikhali, Rangamati

10. **Methodology in brief**

i. Effect of day-length enhancement and night-breaking by artificial lightening on off season fruit production of dragon fruit in Bangladesh

To study the effect of day-length enhancement and night-breaking by artificial lighting on off season fruit production of dragon fruit, these observations were studied in three locations viz. Shibpur, Narsingdi; Joydebpur, Gazipur and Raikhali, Rangamati. The day light prolongation was done by increasing day length with supplemental lighting from 4:00 p.m. to 10:00 p.m. and the night-breaking with supplemental lightening from 10:00 p.m. to 2:00 a.m. as main plot-A. The artificial lightening was done by different type of electric bulbs. There are four treatments: T_1=

100 (±5) watt incandescent bulbs; T_2= 36 (±2) watt CFL bulbs; T_3= 26 (±2) watt CFL bulbs and T_4= 20(±1) watt LED light. No additional light was treated as control. The light enhancement or night-breaking was done by supplemental lighting using different types of electric bulbs. The bulbs line was hanging between two rows of dragon fruit at the high of 0.1 to 1.5m. One bulb was kept in the central point of four dragon fruit plants, for even distribution of light. From 01 November to 31 March the supplemental lightening was applied. The 4 pillars of 5 years old dragon fruit plants, planted in a 36 square meter area was considered a unit plot. Each pit (pillar) was fertilized with 50-75 kg cow dung, 2000g Urea, 1200 g TSP, 1200 g MoP, 450 g Gypsum, 100g Borax and 50g $ZnSO_4$ per year, respectively. The fertilizers were applied in four equal installments. The intercultural operations such as weeding, irrigation etc. were done as and when needed. Data on different phenological, flowering and fruit characteristics were recorded for analysis. Mean data was analyzed statistically and was carried out to analysis of variance using the STAR program.

ii. Effect of cutting length and time of cutting on the success and growth of dragon fruit propagation

The experiment was carried out at Regional Horticulture Research Station, BARI, Shibpur, Narsingdi, from September 2017 to August 2018. The experiment consisted of three length of cutting viz., 10 cm, 20 cm and 30 cm, and six different months viz. October 2017, December 2017, February 2018, April 2018, June 2018, August 2018 and September 2018. The two-factor experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Thus, there were 18 treatment combinations. Twenty cuttings were used in each replication. A total number of 1080 (18×3×20) cuttings were used in the first week of October 2017 to September 2018. Cuttings were prepared from mature stem with deep green color not less than 8 months old and cuttings were placed in 8 x 10-inch size poly bag filled with 50% well decomposed cowdung and 50 % sandy loam soil. The cutting was done on the same day of stem collection in each month with a sharp knife. The prepared cuttings were kept under partial shade made by shade net. Data in respect of days to bud break, per cent success (30 DAG), survivability (60 DAG and 90 DAG), shoot length, shoot breadth, root length per cutting and number of shoots per cutting at 30, 60 and 90 DAC were recorded and analyzed statistically. Mean data was analyzed statistically and was carried out to analysis of variance using the STAR program.

iii. Standardization of the fertilizer dose for dragon fruit in Bangladesh

The experiment was conducted at Regional Horticulture Research Station, BARI, Shibpur, Narsingdi, from September 2017 to July 2018. BARI Dragon fruit-1 was used in the study as variety. The experiment was laid out in a randomized Complete Block Design (Factorial) with 3 replications. Four doses of fertilizers i.e. 100 % (540 g N, 315 g P, 250 g K) ,150 %, 200 %, 250% and control (no fertilizer) along with four types of split application i.e. S_1: six months interval, S_2: four months interval, S_3: three months interval and S_4: two months interval. Each pit (pillar) was fertilized additionally with 75 kg FYM, 450 g Gypsum, 100 g Borax and 50 g $ZnSO_4$ per year, respectively. The additional manures and fertilizers were applied in first installments. Care and management of the plants in the experiment were taken as per need. The data on the

parameters like plant height, base girth, number of primary and secondary branches, length and diameter of terminal shoot, date of first and last flower bud appearance, number of flower bud per plant, date of flower bud initiation, flower bloom, fruit set and harvest, fruit retention per plant at an interval of 7 days up to harvest, fruit characters, TSS and yield were recorded. The collected data were tabulated and statistically analyzed with appropriate design of experiment (Gomez and Gomez, 1984) adopting a statistical programme MSTAT-C. The land type was sandy loam soil and analytical data of soil (Appendix I).

iv. Determination of maturity indices and of dragon fruit

The studies were carried out at the Regional Horticulture Research Centre of Bangladesh Agricultural Research Institute, Shibpur, Narsingdi, Bangladesh during July 2017 to September 2017. BARI Dragon fruit-1 was used in the study as variety. Cumulative rainfall is about 119 mm during August to May with an average of 82.9 % relative humidity. The mean maximum and minimum temperature during cropping period were 36.29 and 21.75^{0}C, respectively. Soil of the experimental farm was clay loam, having pH 6.2 (slightly acidic), which was low in organic carbon (0.95 %), very low in available phosphorus (9 ppm) and low in potash (0.17 meq/100 g soil). The fruit quality, chemical composition and nutritive value were evaluated at the laboratory of Postharvest Technology Division, BARI.

Flowers were tagged at anthesis to determine the stage of fruit development. The pre-selecting development stage and/or days to harvest will be counted from anthesis/fruit setting. Ten randomly selected fruits from each pillar will be harvested at three days intervals started on 22 (±1) days after anthesis (DAA) until 34 DAA (±1) to determine their growth and maturity. Hence there are 5 maturity stages M_1- 22 DAA, M_2- 25 DAA, M_3- 28 DAA, M_4- 31 DAA and M_5- 34 DAA (±1) Characteristic subjective and objective maturity and quality traits will be recorded and evaluated during the developmental stage, harvesting time, immediately after harvest and subsequent storage days and condition. At each harvesting date, out of 10 fruits, 2 were used to determine physicochemical properties like fruit length, diameter, weight, firmness, external and internal colour, dry matter, TSS, pH, acid, Vit. C, sugars and β-carotene content. The rest 8 fruits of immediately after harvest, were sorted for storage studies. Fruits were placed in each of 2L plastic box having some holes, which were weighed before and after keeping the fruits. Boxes were kept in ambient room conditions (25 ± 1 °C and 70 ± 5% RH). One replicated fruit was observed daily up to 60 % rotting. The data were recorded on loss of visual quality, weight loss, firmness, external and internal colour, dry matter, TSS, pH, acid, Vit. C, sugars and β-carotene content. Evaluation of sensory attributes: Sensory evaluation, based on general visual appeals, colour, crispyness, flavour, taste, and visible structural integrity was conducted using a 7-point hedonic scale (Hernandez-Munoz et al., 2008). Fruits were selected on the basis of uniform size, shape and color. Data of various parameters were analyzed for analysis of variance according to Gomez and Gomez (1984) with the help of MSTAT-C programme.

11. Results and discussion:

Experiment-I: Effect of day-length enhancement and night-breaking by artificial lighting on off season fruit production of dragon fruit in Bangladesh

Phenological Responses

Main effect: The main effects of artificial bulbs had significant influence on different phenological responses. First flower bud became visible on 03-03-2018 and took minimum days (123 days) to first flower bud opening from light application was observed in day length enhancement, those on 06-03-2018 and 126 days in night break. The flower was bloomed on 24-03-2018 and took 21 days in day length enhancement, while, flower was bloomed at 30-03-2018 and took 24 days in night break.

Off season fruits were set on 04-04-2018 and days required from flower blooming to fruit set was 11 in day length enhancement, followed by 09-04-2018 and 10 days in night break. The off-season fruit was harvested on 11-05-2018 and days to harvesting from fruit set was 22 days in night break by artificial lightning. In control plants fast flower bud became visible on 22-05-2018, bloomed on 06-06-2018, fruit was set on 11-06-2018 and first fruit was harvested on 03-07-2018 (Table 1). Date of first flower bud visible at plants treated by different electric bulbs from 22-02-2018 (100 (±5) watt incandescent bulbs) to 10-03-2018 (26 (±2) watt CFL bulbs), while untreated control plants produced first flower bud at 22-05-2018 (normal fruiting season). In case of types of bulb for artificial lightning, minimal days to first flower bud opening from light application was obtained in plants treated with 100 (±5) watt incandescent bulbs (114 days) followed by 20 (±1) watt LED light (115 days) and maximum was in control plants (203 days) (Table 1).

Table 1: Main effect of artificial lightening and types of bulb on phenological responses of dragon fruit at Narsingdi

Treatment	Date of first flower bud visible	Days to first flower bud visible from light application (days)	Date of first flower blooming	Days to first flower blooming from flower bud opening (days)	Date of fruit set	Days to first fruit set from first flower blooming (days)	Date of first fruit harvesting	Days to first fruit harvesting from first fruit set (days)
Main effect of type of artificial lightning								
Day length enhancement	03-03-2018	123 b	24-03-2018	21 a	04-04-2018	11 a	01-05-2018	27
Night break	06-03-2018	126 b	30-03-2018	24 b	09-04-2018	10 a	11-05-2018	22
Level of significant	-	**	-	**	-	**	-	ns
Main effect of types of bulb for artificial lightning								
100 wattnormal bulbs	22-02-2018	114 c	18-03-2018	26 a	27-03-2018	9 b	26-04-2018	30 b
36 watt CFL bulbs	09-03-2018	129 b	02-04-2018	24 a	12-04-2018	10 ab	12-05-2018	30 b
26 watt CFL bulbs	10-03-2018	130 b	05-04-2018	26 a	16-04-2018	11a	18-05-2018	32 a
20 watt LED light	23-02-2018	115 c	21-03-2018	26 a	01-04-2018	11a	03-05-2018	33 a
No additional light	22-05-2018	203 a	06-06-2018	15 b	11-06-2018	5 c	04-07-2018	24 c
CV (%)	-	15.68	-	12.50	-	8.55	-	6.87
Level of significant	-	**	-	**	-	**	-	*

Table 2: Effect of artificial lighting on off season dragon fruit production at different locations

Location	Date of first flower bud visible	Date of first flower blooming	Date of fruit set	Date of first fruit harvesting	Flower bud per pillar	Bloomed flower per pillar	No. of fruit per pillar	Yield (g)
Narsingdi	03-03-2018	24-03-2018	04-04-2018	01-05-2018	45 a	36 a	7.5 a	2250 a
Gazipur	21-03-2018	15-04-2018	23-04-2018	27-05-2018	22b	14 b	4 b	1200 b
Rangamati	02-02-2018	24-02-2018	08-03-2018	03-04-2018	13 c	10 c	3 c	1000 c
CV (%)	-	-	-	-	14.53	16.80	11.52	7.32
Level of sign.	-	-	-	-	**	**	**	**

The day length enhancement at different locations had positive effect on off season dragon fruit production. First flower bud became visible at 03-03-2018 in Narsingdi, at 21-03-2018 in Gazipur and at 24-02-2018 in Rangamati. The off season fruits were harvested at 01-05-2018, 27-05-2018 and 03-04-2018 from Narsingdi, Gazipur and Ragamati, respectively. In Narsingdi total 7.5 fruits/pillar were harvested, while only 3 fruits were harvested at Raikhali. The yield per pillar was found maximum (2250 g) in Narsingdi and minimum (1000 g) in Rangamati.

Interaction effect: The interaction had significant influence on different phenological responses. The first flower bud was visible at 17-02-2018 in day length enhancement by 100 (±5) watt incandescent bulbs followed by 19-02-2018 at day length enhancement by 20 (±1) watt LED light, night break by 100 (±5) watt incandescent bulbs (27-02-2018) and night break by 20 (±1) watt LED light (27-02-2018), while plants under untreated control produced first flower buds at normal time which was 22-05-2018. Date of first fruit harvesting was done at 20-04-2018 from plants under day length enhancement by100 (±5) watt incandescent bulbs followed by 20 (±1) watt LED light (28-04-2018). Minimum days required for first flower bud visible for artificial light application in plant under day length enhancement by 100 (±5) watt incandescent bulbs (109 days) followed by day length enhancement by 20 (±1) watt LED light (111 days), night break by 100 (±5) watt incandescent bulbs (119 days) and night break by 20 (±1) watt LED light (119), while plants under untreated control required maximum days for first flower buds from light application (203 days) (Table 2).

Table 2: Interaction effect of type of artificial lightning and types of bulbs on phenological responses of dragon fruit

Treatment	Date of first flower bud visible	Days to first flower bud visible from light application (days)	Date of first flower blooming	Days to first flower blooming from flower bud opening (days)	Date of fruit set	Days to first fruit set from first flower blooming (days)	Date of first fruit harvesting	Days to first fruit harvesting from first fruit set (days)
Day length enhancement								
100 watt incandescent bulbs	17-02-2018	109 d	14-03-2018	25 b	23-03-2018	7 d	20-04-2018	28 c
36 watt CFL bulbs	04-03-2018	124 bc	28-03-2018	24 bc	07-04-2018	10 c	07-05-2018	30 b
26 watt CFL bulbs	07-03-2018	127 bc	02-04-2018	26 a	13-04-2018	11 b	12-05-2018	28 c
20 watt LED light	19-02-2018	111 cd	17-03-2018	26 a	28-03-2018	11 b	28-04-2018	31a
Night break								
100 watt incandescent bulbs	27-02-2018	119 c	22-03-2018	23 c	02-04-2018	11 b	03-05-2018	31a

Treatment	Date of first flower bud visible	Days to first flower bud visible from light application (days)	Date of first flower blooming	Days to first flower blooming from flower bud opening (days)	Date of fruit set	Days to first fruit set from first flower blooming (days)	Date of first fruit harvesting	Days to first fruit harvesting from first fruit set (days)
26 watt CFL bulbs	14-03-2018	134 b	06-04-2018	23 c	17-04-2018	11 b	17-05-2018	30 b
15 watt CFL bulbs	12-03-2018	132 b	07-04-2018	26 a	19-04-2018	12 a	20-05-2018	31a
20 watt LED light	27-02-2018	119 c	25-03-2018	26 a	06-04-2018	12 a	07-05-2018	29 bc
Control								
No additional light	22-05-2018	203 a	06-06-2018	15 d	11-06-2018	5 e	04-07-2018	24 d
CV (%)	-	15.68	-	12.50	-	8.55	-	6.87
Level of significant	-	**	-	**	-	**	-	**

Flowering

Main effect: During off season maximum flower buds (89), bloomed flowers (42.55), harvested fruits (9.50) and percent fruit set (22.33%) was observed at plants under day length enhancement followed by plants under night break (41.50, 14.55, 3.00 and 17.13%, respectively). While plants under untreated control failed to produce any flower bud and fruits at off season. The highest off-season flower buds (137), bloomed flower (34.25) and harvested fruits (10.15) were obtained in plants treated with 100 (±5) watt incandescent bulbs followed by off-season flower budsin 36 (±2) watt CFL bulbs (120.50) while, bloomed flower (32.20) and harvested fruits (6.50) was in 20 (±1) watt LED light. The maximum off season fruits were set in 100 (±5) watt incandescent bulbs (33.66%) followed by 20 (±1) watt LED light (20.19%) and minimum in 26 (±2) watt CFL bulbs (9.38%). The control plants failed to produce any off-season flower and fruit (Table 3).

Table 3: Main effect of artificial lightning and types of bulb on flowering of dragon fruit Narsindi

Treatment	Number of flower bud formed per pillar (up to 31-03-2018)	Number of flowers bloomed per pillar (up to 30-04-2018)	Number of harvested fruits per pillar (up to 30-05-2018)	Percent fruit set (up to 30-05-2018)
Main effect of type of artificial lightning				
Day length enhancement	89.00	42.55	9.50	22.33
Night break	41.50	30.11	6.06	17.13
Main effect of types of bulb for artificial lightning				
100 watt incandescent bulbs	137.00	34.25	10.50	30.66
36 watt CFL bulbs	120.50	27.40	3.50	12.77
26 watt CFL bulbs	81.00	20.35	2.00	9.83
20 watt LED light	100.50	32.20	6.50	20.19
No additional light (Control)	-	-	-	-

Interaction effect: During off season the highest flower buds (108), bloomed flowers (55.25), harvested fruits (17.00) and percent fruit set (15.74%) was observed at plants under day length enhancement by 100 (±5) watt incandescent bulbs (Table 4).

Table 4: Interaction effect of artificial lightning and types of bulbs on flowering of dragon fruit

Treatment	Number of flower bud formed per pillar (up to 31-03-2018)	Number of flowers bloomed per pillar (up to 30-04-2018)	Number of harvested fruits per pillar (up to 30-05-2018)	Percent fruit set (up to 30-05-2018)
Day length enhancement				
100 watt incandescent bulbs	108.00	55.25	17.00	30.77
36 watt CFL bulbs	97.00	42.40	7.00	16.51
26 watt CFL bulbs	64.00	25.35	4.00	15.78
20 watt LED light	87.00	47.20	10.00	21.19
Night break				
100 watt incandescent bulbs	58.00	13.25	4.00	30.19
36 watt CFL bulbs	47.00	12.40	0.00	0.00
26 watt CFL bulbs	34.00	15.35	0.00	0.00
20 watt LED light	27.00	17.20	3.00	17.44
Control				
No additional light (Control)	0.0	0.00	0.00	0.00

Conclusion

It was found that the off-season production of dragon fruits is found successful in Bangladesh by manipulating the day length through artificial lightening using 100-watt incandescent bulb (normal bulb), 20-watt Light Emitting Diode (LED) bulbs or 36-watt compact fluorescent lamps (CFL).

Experimental field view at day time

Day length enhancement by artificial light at night time

Flower bud initiation and flowers formation through artificial light

Flowers are blooming under artificial lightning

Off season fruits are forming under artificial lightning

Director (Res) and Director (SS) of BARI visit experimental field

Experiment-II: Effect of cutting length and time of cutting on the success and growth of dragon fruit propagation

Main Effect of cutting length on dragon fruit propagation

Different cutting lengths significantly influenced the subsequent growth of the dragon fruit cuttings after 6 months of cutting operation (Table 1). In case of days to bud break, the shortest period (62 days) was required by the cutting length of 30 cm, while the longest period (72.90 days) was recorded in the cutting length of 10 cm. The highest 98.65 % successful cuttings were noticed in the cutting length of 30 cm, on the contrary the lowest success 97.66 % were found in the smallest cutting length of 10 cm after 3 months of cutting operation which was statistically similar. The percent survivability was not influenced significantly by different cutting lengths but the subsequent growth was significantly influenced. The longest new shoots (12.50 cm) was recorded in the cuttings of 30 cm length after 30 days of cutting operations as against minimum (8.48 cm) in the cuttings of 10 cm length. Those were longest (42.40 cm) in the cuttings of 30 cm length after 90 days of cutting operations as against minimum (24.55 cm) in the cuttings of 10 cm length. The widest new shoots (1.30 cm) was recorded in the cuttings of 20 cm length after 30 days of cutting operations as against minimum (1.25 cm) in the cuttings of 10 cm length. The longest roots were also found in 30 cm cutting (11.32 cm) after 30 days of cutting operations as against minimum (10.21 cm) in the cuttings of 10 cm length. These results revealed that the longest the cutting, the faster was the rate of regeneration of new shoots, probably associated with the amount of stored food. Gunasena and Pushpa Kumara (2005) found that 60 cm cuttings were better than 10, 20 and 30 cm cuttings. In another experiment, Zee *et.al*. (2004) reported that the 15-20 cm stem sections could be used for dragon fruit propagation.

Table 1. Days to bud Break, percent success and growth of dragon fruit cutting as influenced by cutting length

Cutting Length	Days to bud Break	% Success at			New shoot length (cm)			New shoot breadth (cm)			Root length (cm)		
		30 DAC	60 DAC	90 DAC	30 DAC	60 DAC	90 DAC	30 DAC	60 DAC	90 DAC	30 DAC	60 DAC	90 DAC
10 cm (L_1)	72.90a	97.99	94.47	93.73	8.48c	25.75a	24.55c	1.25 c	2.08b	3.34 c	10.21a	18.28b	29.98c
20 cm (L_2)	69.00b	98.36	97.01	95.84	10.43b	18.75b	34.51b	1.30 a	2.34a	3.50 b	10.42ab	22.10a	38.02b
30 cm (L_3)	62.00b	98.65	97.95	97.19	12.50a	13.68c	42.40a	1.27 b	2.30a	3.52 a	11.32a	22.11a	44.48a
Level of sign.	**	ns	ns	ns	**	**	**	**	**	**	**	**	**
CV (%)	12.30	16.04	8.85	6.76	16.04	8.85	6.76	8.45	16.32	7.45	6.667	10.21	24.51

Main Effect of month of cutting on the success and growth of dragon fruit propagation

Data on success and growth parameters of dragon fruit cutting are presented in Table 2. The earliest bud break was obtained from June operation (41.33 DAC) followed by August (61.22 DAC) and April operation (71.55 DAC), whereas December operation took maximum time (85.44 DAC) to bud break. Time of cutting has no significant effect on percent success at 30, 60 and 90 DAC. The highest success of grafting at 30DAC (99.52 %), 60DAC (98.35 %) and 90DAC (97.83 %) was recorded from June operation. This might be due to the favorable climatic conditions during this period such as moderate temperature and relative humidity (Appendix-II). The lowest success at 30DAC (97.05 %), 60DAC (94.78 %) and 90 DAC (93.20 %) was obtained from December operation. Maximum length of shoot at 30DAC (14.18 cm), shoot breadth (1.46 cm) and root length (14.01 cm) were recorded from the cutting in April, while minimum length of shoot (6.05 cm) and root length (7.15 cm) in February, while shoot breadth (1.07 cm)

in June, respectively. At 90 DAC maximum shoots length (40.33 cm), shoot breadth (3.60 cm) and root length (46.35 cm) was obtained from the cutting of April, August and December cutting compared to minimum shoots length (19.64 cm), shoot breadth (3.30 cm) and root length (31.76 cm) in February, October and June cutting, respectively (Table 2).

Table 2. Days to bud Break, percent success and growth of dragon fruit cutting as influenced by time of cutting

Time of cutting	Days to bud Break	% Success at			New shoot length			New shoot breadth			Root length		
		30 DAC	60 DAC	90 DAC	30 days	60 days	90 days	30 days	60 days	90 days	30 days	60 days	90 days
October (T_1)	81.88a	98.52	97.65	96.68	11.37b	25.44a b	38.31ab	1.22bc	2.30b	3.30	11.28bc	23.04b	40.70b
December (T_2)	85.44a	97.05	94.78	93.20	7.33c	20.18bc	25.64c	1.32ab	2.54a	3.38	10.46c	23.01b	46.35a
February (T_3)	80.88a	98.83	98.10	96.40	6.05c	26.55a	19.64d	1.23a-c	2.40ab	3.48	7.15d	18.43cd	32.65de
April (T_4)	71.55b	98.31	94.80	94.35	14.18a	16.40cd	40.33a	1.46a	2.43ab	3.52	14.01a	25.47a	37.33bc
June (T_5)	41.33d	99.52	98.35	97.83	10.58b	12.37d	33.06bc	1.07c	1.88 c	3.50	12.06b	19.21c	31.76e
August (T_6)	61.22c	98.74	97.41	97.30	10.73b	15.84cd	36.02b	1.30a-c	1.86 c	3.60	11.70bc	19.42c	37.67bc
level of sign.	**	ns	ns	ns	**	**	**	**	**	ns	**	**	**
CV (%)	12.30	16.04	8.85	6.76	16.04	8.85	6.76	8.45	16.32	7.45	6.667	10.21	24.51

Interaction effect of cutting length and cutting time

The treatment combinations exerted significant influence on days to bud break, shoot length, shoot breadth and root length (Table 3 and 4). In April 30 cm cutting showed earlier bud break (31.00 DAC) closely followed by 20 cm and 30 cm cutting in April (40.33 and 41.00 DAC), whereas 10 cm cutting in February took maximum time (119.33 DAC). Cutting success was found maximum (100%, 98.96% and 98.00%) at 30, 60 and 90 DAC, respectively in 30 cm done in June followed by 20 cm done in June. Khatun *et at.* (2006) obtained maximum success in April.

Table 3. Days to bud Break and percent success of dragon fruit cutting as influenced by interaction of time and length of cutting

Combine effect	**Days to bud Break**	**% Success at**		
		30 DAC	**60 DAC**	**90 DAC**
T_1L_1	61.33 d-f	98.24	96.50	95.50
T_1L_2	87.00 b	98.44	97.85	96.75
T_1L_3	97.33 b	98.88	98.60	97.80
T_2L_1	87.00 b	96.45	91.90	90.99
T_2L_2	85.67 b	97.21	95.75	92.85
T_2L_3	83.67 bc	97.50	96.70	95.77
T_3L_1	119.33 a	98.54	97.54	95.50
T_3L_2	68.00 de	98.75	98.00	96.20
T_3L_3	55.33 e-g	99.21	98.75	97.50
T_4L_1	90.33 b	97.50	90.40	90.30
T_4L_2	93.33 b	98.62	96.55	95.80
T_4L_3	31.00 i	98.82	97.45	96.95

Combine effect	Days to bud Break	% Success at		
		30 DAC	60 DAC	90 DAC
T_5L_1	42.67 g-i	98.99	97.60	97.50
T_5L_2	40.33 hi	99.56	98.50	97.99
T_5L_3	41.00 hi	100.00	98.96	98.00
T_6L_1	53.67 f-h	98.99	96.50	96.40
T_6L_2	58.67 d-f	99.00	97.75	97.70
T_6L_3	71.33 cd	98.24	97.99	97.80
level of sign.	**	ns	ns	ns
CV (%)	12.30	16.04	8.85	6.76

Maximum shoot length (17.33, 34.66 and 54.30 cm) was obtain 30 cm cutting in October at 30, 60 and 90 DAC, respectively. Shoot diameter at 30 DAC, 60 DAC and 90 DAC were found maximum in 10 cm cutting of December (1.56 cm), 30 cm cutting of December (2.86 cm) and 30 cm cutting of June (4.03 cm), respectively. The highest root length at 30 DAC, 60 DAC were found in 30 cm cutting of April and the highest root length at 90 DAC were found in 30 cm cutting of December operation.

Table 4. Growth of dragon fruit cutting as influenced by interaction of time and length of cutting

Combine effect	New shoot length			New shoot breadth			Root length		
	30 days	60 days	90 days	30 days	60 days	90 days	30 days	60 days	90 days
T_1L_1	7.10 f-h	11.90 g-i	22.67 f-h	1.07 c-e	2.16 c-g	3.26 b-d	11.96 cd	18.40 e-g	29.53 i
T_1L_2	9.66 d-f	14.00 e-i	37.97 de	1.30 de	2.33 b-f	3.33 b-d	10.23 d-g	23.60 c	38.80 e-g
T_1L_3	17.33 a	34.66 a	54.30 a	1.30 de	2.40 b-e	3.30 b-d	11.66 c-f	27.13 b	53.76 b
T_2L_1	7.66 f-h	7.16 i	11.30 i	1.53 a	2.30 b-f	3.33 b-d	9.33 fg	14.40 i	27.53 i
T_2L_2	11.00 c-f	16.96 c-i	24.97 fg	1.36 a-d	2.46 a-d	3.40 b-d	11.73 c-e	30.06 a	51.20 bc
T_2L_3	10.00 d-f	23.40 c-e	40.67 cd	1.06 b-e	2.86 a	3.43 b-d	10.33 d-g	24.56 c	60.33 a
T_3L_1	4.13 h	8.86 hi	13.07 hi	0.97 f	2.00 e-i	3.03 b	5.5 6i	12.96 ij	18.76 j
T_3L_2	9.06 e-g	15.26 c-i	22.63 f-h	1.30 de	2.63 ab	3.70 a-c	6.03 hi	20.13 de	36.96 f-h
T_3L_3	4.96 gh	13.00 f-i	23.23f-h	1.43 a-c	2.56 a-c	3.73 a-c	9.87 d-g	22.20 cd	42.23 d-f
T_4L_1	15.10 a-c	17.46 c-h	28.20 ef	1.56 a	2.40 b-e	3.70 a-d	6.20 hi	17.63 fg	28.73 i
T_4L_2	14.06 b-d	25.30 bc	42.07 b-d	1.50 a	2.40 b-e	3.56 a-c	16.63 b	28.96 ab	40.30 e-g
T_4L_3	13.83 b-d	33.56 ab	50.73 a-c	1.33 a-e	2.50 a-d	3.30 a-d	19.20 a	29.83 a	42.96 de
T_5L_1	10.50 d-f	10.73 hi	15.23 g-i	0.93 e	1.86 g-i	3.03 a-d	11.80 cd	19.80 d-f	27.86 i
T_5L_2	13.70 b-d	21.30 c-g	31.30 d-f	1.03 c-e	1.96 f-i	3.43 a-d	11.53 c-f	17.20 gh	31.53 hi
T_5L_3	3.33 h	24.90 b-d	52.67 ab	1.26 a-e	1.83 g-i	4.03 a	12.86 c	20.63 de	35.90 gh
T_6L_1	11.26 c-f	22.96 c-f	60.80 a	1.53 a	1.70 i	3.86 a-d	18.30 ab	29.70 a	46.20 cd
T_6L_2	7.10 f-h	15.06 d-i	31.47 d-f	1.33 a-e	2.16 c-g	3.60 b-d	10.86 c-f	17.10 gh	37.53 e-g
T_6L_3	7.56 f-h	11.16 hi	15.80 g-i	1.03 c-e	1.73 hi	3.33 ab	5.93 i	11.46 j	29.30 i
level of sign.	**	**	**	**	**	**	**	**	**
CV (%)	16.04	8.85	6.76	8.45	16.32	7.45	6.667	10.21	24.51

Conclusion

The study revealed that irrespective of time of operation, cutting length is important for dragon fruit propagation. The longer cuttings showed superiority over shorter cuttings. The cutting prepared with 30 cm length performed better followed by cuttings of 20 and 10 cm length in all the growth parameters. But considering number of propagule 20 cm length is suitable. Under this experiment October 2017 to September 2018 operation perform similar results. On the other hand, the cuttings are to be planted in the field for its performance up to yield then it may be possible to recommend a suitable cutting length and time of cuttings for its effective multiplication.

Pictorial view of experimental field

Different stages 10 cm cutting

Different stages 20 cm cutting

Different stages 20 cm cutting

Experiment-III: To standardize the fertilizer dose for dragon fruit in Bangladesh

Effect of split application of fertilizer on plant growth of dragon fruit

Significant variation was noticed among the treatments in terms of all the vegetative characters of dragon fruit plants (Table 1). The longest plant (252.94 cm) was found in 200% of the fertilizer dose applied in two months interval followed by 250% of the fertilizer dose applied two months interval (251.33 cm), 250% of the fertilizer dose applied three months interval (250.77 cm), 250% of the fertilizer dose applied six months interval (248.33 cm), 200% of the fertilizer dose applied three months interval (243.64 cm), 250% of the fertilizer dose applied four months interval (239.88 cm) and 200% of the fertilizer dose applied two months interval (238.72 cm) and those were statistically similar. Number of main branches found maximum in 250% of the fertilizer dose applied in two months interval (22.99). New shoot length was noted the height in 250% of the fertilizer dose applied in two months interval (28.12 cm) closely followed by 250% of the fertilizer dose applied three months interval (27.05 cm). While plant under control plot resulted the shortest plan (150.32 cm), minimum number of main brunches (4.23) and the lowest new shoot length (7.45 cm).

Table 1. Effect of split application of fertilizer on plant height, number of main branches, shoot length and shoot breadth

Treatment	Plant height (cm)	No. main branch	New shoot length (cm)	New shoot breadth (cm)
S_1D_1	182.22c	7.11b	11.44c	8.94 c
S_1D_2	233.02ab	7.86b	13.10c	9.16 c
S_1D_3	238.72a	7.99b	15.07a-c	11.16 b
S_1D_4	248.33a	9.33b	22.38 a-c	11.55 b
S_2D_1	190.44bc	10.99ab	15.77a-c	11.66 b
S_2D_2	224.11a-c	10.93ab	16.83 a-c	11.83 b
S_2D_3	227.22a-c	12.88ab	14.60a-c	11.76 b
S_2D_4	239.88a	11.11ab	23.72 a-c	12.61 ab
S_3D_1	229.61a-c	11.33ab	14.38 bc	12.16 ab
S_3D_2	239.55a	11.10ab	17.66 a-c	12.44 ab
S_3D_3	243.00a	11.88ab	16.11 a-c	12.44 ab
S_3D_4	250.77a	12.55ab	27.05a	13.55 a
S_4D_1	220.18a-c	14.10ab	17.88 a-c	12.81 ab
S_4D_2	243.64a	15.55ab	20.77a-c	12.83 ab
S_4D_3	252.94a	16.60ab	21.51a-c	13.72 a
S_4D_4	251.33a	22.99a	28.12a	13.88 a
Control	150.32 d	4.23 c	7.45 d	6.20 d
level of sign.	**	**	**	**
CV (%)	6.24	11.35	9.04	11.24

S_1 6 months interval S_2 4 months interval S_3 3 months interval
S_4 2 months interval and Control No fertilizer applied
D_1 100 % D_2 150 % D_3 200 % and D_4 250 % of 540 g N, 315 g P, 250 g K2O

Effect of split application of fertilizer on Number of flower bud, Percent fruit set, and Number of fruits

Significant variation was noticed among the treatments in terms of on plant height, number of main brunches, shoot length and shoot breadth of dragon fruit plants (Table 2). Maximum number of flower buds (76) were recorded in S_2D_4 followed by S_3D_4 (72) and S_4D_4 (70) while minimum (13) flower buds were found in control plant. The height number of flowers were bloomed (68) in S_3D_4 and S_2D_4 followed by S_4D_3 (65) and S_4D_4 (60) while the lowest (5) flowers were bloomed in control plant. Maximum fruits were harvested (22) from S_2D_4 followed by S_4D_2 (21), S_4D_4 (20), S_3D_4 (20) and S_1D_4 (20) while the control plant produced only one fruit. Percent fruit set was found the highest (36.36%) from S_1D_4 followed by S_2D_2 (36.21%), S_1D_3 (34.69%), S_2D_1 (32.50%), S_2D_4 (32.35%) and S_4D_4 (32.26%). The percent fruit set was the lowest in control plant (20.00%).

Table 2. Effect of split application of fertilizer on Number of flower bud, Percent fruit set, and Number of fruits

Treatment	Number of flower bud formed per pillar	Number of flowers bloomed per pillar	Number of harvested fruits per pillar	Percent fruit set
S_1D_1	40 c	35 d	9 c	25.71
S_1D_2	53 c	47 c	14 b	29.79
S_1D_3	55 c	49 c	17 ab	34.69
S_1D_4	62 b	55 bc	20 a	36.36
S_2D_1	47 c	40 c	13 b	32.50
S_2D_2	65 b	58 b	21 a	36.21
S_2D_3	65 b	59 b	17 ab	28.81
S_2D_4	76 a	68 a	22 a	32.35
S_3D_1	47 c	45 c	10 bc	22.22
S_3D_2	53 c	50 c	13 b	26.00
S_3D_3	68 b	60 b	17 ab	28.33
S_3D_4	72 a	68 a	20 a	29.41
S_4D_1	58 bc	55 bc	12 b	21.82
S_4D_2	62 b	60 b	19 a	31.67
S_4D_3	68 b	65 a	18 a	27.69
S_4D_4	70 ab	62 b	20 a	32.26
Control	13 d	5 e	1 d	20.00
level of sign.	**	**	**	ns
CV (%)	9.54	13.25	9.04	14.55

Effect of split application of fertilizer on fruit weight, fruit length, fruit breadth, peel weight, edible portion and date of flower bud initiation

Significant variation was noticed among the treatments in terms of on fruit weight, fruit length, fruit breadth, peel weight, edible portion and date of flower bud initiation of dragon fruit plants (Table 3).

The heaviest fruits (380 g), maximum fruit length (10.20 cm) and breadth (9.00 cm) were recorded in S_3D_4 followed by S_3D_3 (377 g, 9.40 cm and 8.50 cm, respectively) and S_2D_3 (375 g, 9.30 cm and 8.40 cm, respectively) while lightest fruits (114), minimum fruit length and breadth (6.00 and 5.20 cm, respectively) were found in control plant. The height edible portion (87.85%) were recorded in S_4D_2 followed by S_3D_4 (87.77%) and S_3D_3 (86.62%) while the lowest (72.25%) were in control plant.

Table 3. Effect of split application of fertilizer on fruit weight, fruit length, fruit breadth, peel weight, edible portion and date of flower bud initiation

Treatment	Fruit weight (g)	Fruit length (cm)	Fruit breadth (cm)	Peel weight (g)	Edible portion (%)	Date of flower bud initiation
S_1D_1	172 c	7.10	7.30	36.00 f	79.50 ab	04/07/2018
S_1D_2	306 ab	8.10	8.00	97.00 a	84.21 a	20/05/2018
S_1D_3	255 bc	8.40	7.80	76.00 c	80.21 ab	14/06/2018
S_1D_4	348 ab	9.10	8.20	91.50 a	85.50 a	14/06/2018
S_2D_1	128 ce	7.00	8.00	43.10 e	74.24 b	04/06/2018
S_2D_2	200 c	7.80	6.80	76.00 c	81.12 ab	15/05/2018
S_2D_3	375 a	9.30	8.40	75.37 c	79.90 ab	05/06/2018
S_2D_4	230 bc	8.20	6.90	56.00 d	83.30 ab	20/05/2018
S_3D_1	264 b	8.50	7.50	76.00 c	84.45 a	05/07/2018
S_3D_2	126 ce	6.60	6.20	50.00 d	74.20 b	05/07/2018
S_3D_3	377 a	9.40	8.50	75.40 c	86.62 a	06/04/2018
S_3D_4	380 a	10.20	9.00	70.00 c	87.77 a	24/06/2018
S_4D_1	214 c	9.10	8.30	71.00 c	81.75 ab	05/08/2018
S_4D_2	332 ab	8.90	6.80	87.30 b	87.85 a	05/06/2018
S_4D_3	284 b	8.40	7.70	78.00 c	84.45 a	06/07/2018
S_4D_4	250 bc	8.50	7.50	75.00 c	81.25 ab	17/07/2018
Control	114 e	6.00	5.20	38.50 f	72.25 b	17/05/2018
level of sign	**	ns	ns	**	**	
CV (%)	6.52	8.06	7.45	8.35	5.74	

Conclusion

It was observed that higher doses of fertilizers had positive effect on plant growth and reproductive behavior of dragon fruit compared to control (no fertilizer). Considering growth, flowering and fruiting, the plants treated with 250 % of the fertilizer dose (540g N, 315g P, and 250g K_2O) applied in three to four split applications.

Effect of split application of fertilizer on dragon fruit

Experiment-IV: Determination of maturity indices of dragon fruit

Physical characters of dragon fruit: Dragon fruit under this experiment showed gain in weight with extending the harvest time from flower anthesis (Table 1). The lighter fruits (242.00 g) were harvested after 22 days after anthesis, which increased steadily until 34 DAA. However, the maximum fruit weight of 382 g was obtained after 34 days after anthesis, which was statistically different (P≤0.05) with other fruit weight under studied. Both length and diameter of dragon fruit significantly (P≤0.05) increased with the increase of harvesting time from anthesis (Table 1). Ortiz and Takahashi (2015) found that fruit muss increase from 293.10 to 416.20 g from 22 DAA to 32 DAA. The longest fruit (9.90 cm) was harvested after 34 days of anthesis, which was significantly similar (P≤0.05) with fruits that harvested on 31 DAA (9.50 cm) and 28 DAA (9.10 cm). Whereas, the shortest fruit length (8.30 cm) were obtained from harvesting after 22 days of anthesis. Similarly, fruits with maximum diameter of 8.20 cm were harvested after 34 days of anthesis followed by 31 DAA (8.40 cm), while shortest was in 22 DAA (7.80 cm). In contrast, Centurion Yah *et al*. (2008) found an increase in fruit length and diameter during maturation with a maximum of 8.9 and 8.2 cm, respectively at 31 DAA for *H. undatus* fruit. In a study of reproductive phenology and fruit quality during the summer and autumn at Sinaloa, Mexico, Osuna Enciso *et al*. (2007) reported a mean fruit length and diameter of 14.3 and 7.9 cm, respectively for the same species. From the results, it was found that percent edible portion of dragon fruit was not affected by different harvest maturity. The percent edible portion ranged 78.51 to 82.72% was found during harvesting from 22 to 34 DAA, which was not significantly different among harvesting times.

Dry matter content and shelf life: Dry matter content of dragon fruit was found lower (5.09 %) in fruits that harvested after 22 days of anthesis and then steadily increased with extending the harvest duration (Table 1). The maximum dry matter (6.30 %) was gained by fruits that harvested after 34 days of anthesis. Significantly (P≤0.05) similar dry matter was found in fruits that harvested on 31 DAA. As changes in the dry matter content over harvesting period, similar trend was also observed for shelf life of fruits. The shelf life of 22 day's harvested fruits was only 16.70 days under ambient room condition, which steadily increased with increase the harvest duration and reached the maximum shelf period of 21.30 days for fruits that harvested after 28 days of anthesis. After that shelf life was decreased and that was 17.20 at 31 DAA and reached minimum 14.20 days at 34 DAA (Table 1).

Table 1. Changes in different physical characters, dry matter content and shelf life of dragon fruit at different maturity stages

Maturity stage	Fruit weight (g)	Fruit length (cm)	Fruit breadth (cm)	Pulp weight (g)	Peel weight (g).	Edible portion (%)	Pulp thickness (cm)	Peel thickness (cm)	Dry mater (%)	Shelf life (days)
22 DAA	242.00 e	8.30 c	7.80 e	190.00 d	52.00 c	78.51	6.42 c	0.69 a	5.09 c	16.70 b
25 DAA	295.00 d	8.50 bc	7.90 d	235.00 c	60.00 b	79.66	7.00 b	0.45 b	5.42 b	18.40 ab
28 DAA	350.00 c	9.10 ab	8.00 c	286.00 b	64.00 a	81.71	7.20 ab	0.40 bc	6.14 a	21.30 a
31 DAA	360.00 b	9.50 a	8.10 b	295.00 b	65.00 a	81.94	7.50 a	0.35 c	6.22 a	17.20 ab
34 DAA	382.00 a	9.90 a	8.20 a	316.00 a	66.00 a	82.72	7.60 a	0.30 c	6.30 a	14.20 c
F-value	*	*	*	*	*	ns	*	*	*	*
CV (%)	4.9	2.6	2.8	4.5	2.5	0.9	4.5	3.7	2.7	6.7

Values in each column followed by the same letter (s) are not significantly different at 5% level. *Significant at 5% level; ns= Not significant.

However, no significant (P≤0.05) differences were observed in regarding the shelf life among fruits harvested after 25 and 31 days of anthesis. In this study, it was found that over mature fruits which harvested after 31 -34 days of anthesis had poor shelf life compared to the mature fruits. Results of this study are in agreement with Wills et al. (2007) who stated that respiration rate per unit weight is highest for the immature and over mature fruits or vegetables and then steadily declines with age and product that respires very fast will have a short storage life and vice versa.

Fruit surface colour: Surface colour changes of dragon fruit were monitored by measuring lightness (*L**), chroma (*C**), and hue angle (*h°*) during harvesting periods. Values are presented in Table 2a-c, respectively. The intensity of green colour of fruit skin was slowly decreased with extend the harvesting time and turned to pink as evidenced by increasing values of *L** and *C** (Table 2a &b). The initial values of *L** and *C** were 42.50 and 37.25, respectively, were recorded in fruits that harvested after 22 DAA, which were attained 34.50 and 39.90, respectively at 14 days of storage. After that time, both were gradually increased and reached to 37.15 and 30.10, respectively, at 34 DAA and after 14 days of storage attained 28.50 and 38.50, respectively. Results of the present study are partially supported by the findings of Castillo-Martínez and Ortíz-Hernández (1994) and Centurion Yah *et al*. (2008). According to Castillo-Martínez and Ortíz-Hernández (1994) and Centurion Yah *et al*. (2008), the first change in *H. undatus* pericarp color occurs at 24 to 25 DAA; however, Ortiz and Takahashi (2015) found the change occurred at 28 to 29 DAA. According to Nerd *et al*. (1999) and Centurion Yah *et al*. (2008), the pericarp of pitaya fruits becomes completely red after 4 to 5 days after the first change in color; we obtained similar results in showing this change occurred between the 25th and 32nd DAA. A study in Vietnam, where *H. undatus* fruits are harvested when they turn red, found that the change occurs between the 28th and 30th DAA (To et al., 2002).

Table 2a. Changes in Lightness *(L*)* of fruit surface of dragon fruit at different maturity stages

Maturity stage	Fresh	D-2	D-4	D-6	D-8	D-10	D-12	D-14
22 DAA	42.50 c	44.50 b	46.75 a	43.34 b	42.65 a	40.50 b	37.75 b	34.50 b
25 DAA	44.90 b	45.50 ab	45.20 b	44.60 a	42.85 a	41.50 a	40.80 a	37.85 a
28 DAA	46.20 a	46.50 a	44.75 c	43.75 b	42.80 a	41.75 a	40.90 a	38.50 a
31 DAA	40.20 d	39.78 c	38.50 d	37.75 c	35.50 b	33.42 c	30.88 c	29.45 c
34 DAA	37.15 e	36.90 d	35.75 e	35.00 d	34.50 b	32.80 c	29.50 c	28.50 c
F-value	*	*	*	*	*	*	*	*
CV (%)	5.9	7.1	2.7	6.4	3.8	7.3	8.0	5.6

Table 2b. Changes in Chroma (*C**) of fruit surface of dragon fruit at different maturity stages

Maturity stage	Fresh	D-2	D-4	D-6	D-8	D-10	D-12	D-14
22 DAA	37.25 a	35.50 a	33.78 b	33.12	34.80	35.54	37.50 c	39.90 c
25 DAA	35.45 b	34.50 b	33.95 a	34.50	35.47	36.25	38.75 b	40.10 b
28 DAA	31.75 c	31.05 c	32.45 c	33.78	35.45	36.89	40.35 a	42.50 a
31 DAA	30.46 cd	30.25 d	31.00 e	31.85	32.15	34.50	37.82 c	39.50 c
34 DAA	30.10 d	31.00 c	31.50 d	31.25	31.58	33.12	36.75 d	38.50 d
F-value	*	*	ns	ns	ns	ns	*	*
CV (%)	4.7	5.6	6.9	7.9	5.7	7.9	4.9	3.6

In this study, the degree of hue angle of dragon fruit showed a significant decrease in hue angle with extent the harvest period. When harvesting began, the fruit pericarp was green-yellow (120.30°); as

maturation advanced the hue changed to 64.75° at 25 DAA (as red coloration began to develop); the fruits become completely red at the 31st DAA (28°) and increased in intensity at 34 DAA (54.55°). Similarly, Centurion Yah et al. (2008) reported a decrease in mean color angle values during maturation from 116.6° (25 DAA), 108.3° (27 DAA), 91.4° (29 DAA), to 51.0° (31 DAA).

Table 2c. Changes in Hue angle (h^o) of fruit surface of dragon fruit at different maturity stages

Maturity stage	Fresh	D-2	D-4	D-6	D-8	D-10	D-12	D-14
22 DAA	120.30 a	126.43 a	96.20 a	88.64 a	72.50 a	58.45 a	40.43 a	26.97 c
25 DAA	98.52 c	105.25 b	86.53 b	75.45 b	64.25 b	53.54 b	36.40 c	22.55 d
28 DAA	108.75 b	90.88 c	80.67 c	65.21 c	50.25 d	44.54 c	38.50 bc	33.50 a
31 DAA	91.70 d	84.54 d	72.20 d	65.55 c	57.43 c	45.55 c	32.47 d	28.10 b
34 DAA	54.55 e	52.74 e	45.50 e	32.53 d	25.43 e	18.50 d	14.00 e	12.75 e
F-value	**	**	*	*	*	*	*	*
CV (%)	6.7	8.6	5.8	4.6	7.5	9.1	3.2	4.9

Values in each column followed by the same letter (s) are not significantly different at 5% level. *Significant at 5% level; ns= Not significant.

Flesh firmness: Flesh firmness is a critical quality attribute in the consumer acceptability of fresh fruits and vegetables. The maximum firmness of dragon fruit that harvested after 22 days of anthesis was recorded 13.75 kgf cm^{-2}, which progressively decreased with extending the harvesting time from anthesis and reached the minimum firmness of 9.85 kgf cm^{-2} after 34 days of anthesis. After 14 days of storage firmness attained 10.98 kgf cm^{-2} that of fruits harvested at 22 DAA, while that of 34 DAA was attained 7 kgf cm^{-2}. Significantly similar ($P \leq 0.05$) firmness was found in fruits that harvested after 28 DAA (11.25 kgf cm^{-2}) and 31 DAA (10.08 kgf cm^{-2}) (Table 3). Result of this study supported the findings of *Tadesse et al.* (2002), who reported that fruit age was negetavily correlated with fruit firmness.

Table 3. Changes in firmness (kgf cm^{-2}) of dragon fruit at different maturity stages

Maturity stage	Fresh	D-2	D-4	D-6	D-8	D-10	D-12	D-14
22 DAA	13.25	13.54 a	12.37 a	12.12 a	11.59 a	11.27	11.07	10.98 a
25 DAA	12.45	12.75 b	11.20 b	11.09 bc	10.78 b	10.25	10.08	10.00 b
28 DAA	11.25	11.05 c	10.15 c	10.02 c	9.75 c	9.20	9.10	9.00 c
31 DAA	10.08	9.57 d	9.02 d	8.98 d	8.57 d	8.10	7.95	7.52 d
34 DAA	9.85	8.21 e	7.95 e	7.73 e	7.55 e	7.24	7.05	7.00 d
F-value	ns	*	*	*	*	ns	ns	*
CV (%)	7.7	4.3	6.4	8.5	4.6	9.1	8.2	6.9

Values in each column followed by the same letter (s) are not significantly different at 5% level. *Significant at 5% level; ns= Not significant.

Vitamin C, TSS, and pH: It is evident that the length of harvesting time induced significant variation in vitamin C content of dragon fruit (Table 4). The vitamin C content was found minimum (62.55 mg/100 g) at fruits harvested at 22 DAA, which was gradually increase with the harvest time and attained maximum (78.45 mg/100 g) at fruit harvested at 28 days of anthesis. But with the extending of harvest length, the content gradually decreased and reached the level of 70.54 mg/100 g after 34 days of anthesis. During storage vitamin C content were loses and after 14 days of storage that was 17.42 mg/100 g for fruits of 22 DAA and 13.45 mg/100 g for 34 DAA. The losses of vitamin C can be continued

through maturity, postharvest handling, processing, cooking, and storage of fruits and vegetables (Lee and Kader, 2000). Results of the present study are in agreement with Nagy (1980), who reported that immature fruits contained the highest concentration of ascorbic acid, whereas mature fruits contained the least.

The changes in TSS content of dragon fruit with harvesting length is presented in Table 5. The TSS of fruit samples harvested after 22 days of anthesis was fairly low (10.50 %), which was slowly increased with increase of harvesting time. The TSS content reached the maximum level of 12.8%, when fruits were harvested after 31 days of anthesis. No significant (P≤0.05) difference was observed regarding the TSS content in fruits that harvested between 25 and 34 DAA. The increase in TSS of dragon fruit with maturity is probably a result of increased hexose sugar accumulation during fruit ripening (Nielsen *et al*., 1991) as there is a close positive correlation between the rise in TSS and soluble sugars (Mendlinger *et al*., 1992).

Table 4. Changes in vitamin C (mg/100 g) content of dragon fruit at different maturity stages

Maturity stage	Fresh	D-2	D-4	D-6	D-8	D-10	D-12	D-14
22 DAA	62.55 e	65.50 d	59.39 b	54.35 b	40.12 c	31.52 c	28.27 c	17.42 c
25 DAA	67.50 d	72.92 b	60.50 b	55.55 b	42.20 b	37.50 b	35.20 b	37.50 b
28 DAA	78.45 a	82.92 a	72.75 a	68.50 a	65.50 a	60.32 a	57.50 a	50.21 a
31 DAA	74.75 b	70.10 c	60.21 b	51.50 c	42.35 b	33.50 c	25.38 d	18.25 c
34 DAA	70.54 c	47.02 e	52.85 d	40.21 d	30.25 d	22.75 d	19.68 e	13.45 d
F-value	*	*	*	*	*	*	*	*
CV (%)	4.5	5.2	5.4	7.4	6.7	3.5	7.3	5.6

Values in each column followed by the same letter (s) are not significantly different at 5% level. *Significant at 5% level; ns= Not significant.

Table 5. Changes in percent total soluble solids (TSS) content of dragon fruit at different maturity stages

Maturity stage	Fresh	D-2	D-4	D-6	D-8	D-10	D-12	D-14
22 DAA	10.5 b	11.3 c	12.0	12.2	11.9	11.5	11.2 c	11.0 b
25 DAA	11.7 ab	12.4 b	12.7	12.8	12.5	12.3	12.2 b	12.0 ab
28 DAA	12.2 a	12.6 b	13.0	13.7	13.5	13.4	13.2 a	12.8 a
31 DAA	12.8 a	13.1 a	13.5	13.7	13.4	13.2	13.0 a	12.5 a
34 DAA	12.5 a	12.8 b	13.2	13.3	13.4	13.1	12.8 ab	12.2 a
F-value	*	*	ns	ns	ns	ns	*	*
CV (%)	6.9	6.3	6.9	5.4	5.5	7.9	6.5	7.9

Values in each column followed by the same letter (s) are not significantly different at 5% level. *Significant at 5% level; ns= Not significant.

The changes in pH of dragon fruit as a function of different harvesting time are shown in Table 6. From the results, it was found that pH of dragon fruit was not affected by different harvest maturity. The pH ranged 5.05 to 5.50 was found during harvesting from 25 to 34 DAA, which was not significantly different among harvesting times. Similar results were also found by Fox *et al*. (2005) who reported that pH of dragon fruit was not affected by different harvesting time, which ranged 4.9 to 5.1.

Table 6. Changes in pH content of dragon fruit at different maturity stages

Maturity stage	Fresh	D-2	D-4	D-6	D-8	D-10	D-12	D-14
22 DAA	5.30	5.36	5.49	5.50	5.35	5.22	5.19	5.09
25 DAA	5.05	5.11	5.14	5.19	4.98	4.96	4.95	4.65
28 DAA	5.14	5.18	5.22	5.20	5.13	5.09	5.05	4.95
31 DAA	5.39	5.53	5.43	5.37	5.29	5.25	5.21	5.15
34 DAA	5.50	5.65	5.61	5.55	5.48	5.36	5.28	5.20
F-value	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)	7.2	8.1	3.2	4.8	3.2	4.2	5.7	6.1

Values in each column followed by the same letter (s) are not significantly different at 5% level. *Significant at 5% level; ns= Not significant.

Tritatable acidity and total sugar: It is evident that the percent tritatable acidity of fresh dragon fruit gradually increase with the increase in days after anthesis and it was 0.91% at 22 DAA and attained 0.60% at 31 DAA, after that it was slightly increase. After 14 days of storage the tritatable acidity of fruits of 22 DAA was 0.45% and at 34 DAA it was 0.18% (Table 7).

Table 7. Changes in titratable acidity (%) of dragon fruit at different maturity stages

Maturity stage	Fresh	D-2	D-4	D-6	D-8	D-10	D-12	D-14
22 DAA	0.91 a	1.05 a	1.10 a	0.90 a	0.85 a	0.78 a	0.60 a	0.45 a
25 DAA	0.85 b	0.90 b	0.86 b	0.73 b	0.65 b	0.52 b	0.44 b	0.36 b
28 DAA	0.72 c	0.80 c	0.75 c	0.69 b	0.59 b	0.52 b	0.45 b	0.32 b
31 DAA	0.60 d	0.58 d	0.50 d	0.42 c	0.37 c	0.29 c	0.25 c	0.19 c
34 DAA	0.62 d	0.60 d	0.45 d	0.40 c	0.38 c	0.30 c	0.25 c	0.18 c
F-value	*	*	*	*	*	*	*	*
CV (%)	3.6	2.3	1.9	2.5	1.6	3.5	2.3	3.8

Values followed by the same letter (s) not significantly differed at 5% level. *Significant at 5% level; ns= Not significant.

The total sugar content was found minimum (7.5%) at fruits harvested at 22 DAA, which was gradually increase with the harvest time and attained maximum (8.8%) at fruit harvested at 31 days of anthesis. But with the extending of harvest length, the content decreased and reached the level of 8.4% after 34 days of anthesis. During storage total sugar content were gradually increase up to days 10 for 22 DAA and 25 DAA, but up to days 6 for 28 DAA and 31 DAA. After 14 days of storage that was 7.72% for fruits of 22 DAA and 7.10% for 34 DAA (Table 8). The change of titratable acidity can be continued through conversion of acid in to sugar during maturity and storage of fruits and vegetables (Lee and Kader, 2000).

Table 8. Changes in total sugar content (%) of dragon fruit at different maturity stages

Maturity stage	Fresh	D-2	D-4	D-6	D-8	D-10	D-12	D-14
22 DAA	7.5 d	7.70 b	7.89	7.95	8.05 c	8.10 b	7.84 c	7.72 b
25 DAA	8.2 c	8.41 a	8.69	8.80	8.92 ab	8.95 a	8.85 a	7.76 b
28 DAA	8.5 bc	8.77 a	8.97	9.10	9.05 a	8.85 a	8.75 a	8.55 a
31 DAA	8.8 a	8.95 a	8.62	8.65	8.35 bc	8.20 b	8.05 b	7.80 b
34 DAA	8.4 bc	8.50 a	8.16	8.10	7.65 d	7.48 c	7.35 d	7.10 c
F-value	*	*	ns	ns	*	*	*	*
CV (%)	6.6	4.8	6.2	7.8	0.9	2.8	0.8	3.8

Values in each column followed by the same letter (s) are not significantly different at 5% level. *Significant at 5% level; ns= Not significant.

Reducing sugar and *β* carotene content: The changes in reducing sugar content (%) of dragon fruit with date after harvest is presented in Table 9. The reducing sugar content (%) of fruit samples harvested after 22 days of anthesis was fairly low (3.10 %), which was slowly increased with increase of harvesting time. The reducing sugar content (%) reached the maximum level of 3.62%, when fruits were harvested after 34 days of anthesis. No significant (P≤0.05) difference was observed regarding the reducing sugar content (%) in fruits that harvested between 25 and 34 DAA. The increase in reducing sugar content of dragon fruit with maturity is probably a result of increased hexose sugar accumulation during fruit ripening (Nielsen *et al*., 1991).

The changes in *β* carotene content (µg/100 g) of dragon fruit as a function of different harvesting time are shown in Table 10. From the results, it was found that pulp *β* carotene content of dragon fruit was affected by different harvest maturity. The *β* carotene content (µg/100 g) gradually increase from 5.01 (22 DAA) to 5.58 µg/100 g (28 DAA) than it was slightly decrease and attained 5.40 µg/100 g at 34 DAA, which was significantly different among harvesting times. After 14 days of storage *β* carotene content (µg/100 g) of dragon was found 5.15 µg/100 g at 22 DAA and 6.70 µg/100 g at 34 DAA.

Table 9. Changes in reducing sugar content (%) of dragon fruit at different maturity stages

Maturity stage	Fresh	D-2	D-4	D-6	D-8	D-10	D-12	D-14
22 DAA	3.10 b	3.30	3.49	3.55	3.75	3.92	3.84	3.80
25 DAA	3.25 b	3.31	3.79	3.80	3.92	3.95	3.85	3.76
28 DAA	3.35 b	3.47	3.77	3.90	4.20	4.15	4.05	3.98
31 DAA	3.50 b	3.78	3.95	4.20	4.10	3.90	3.85	3.80
34 DAA	3.62 b	3.70	3.85	4.16	3.95	3.68	3.55	3.40
F-value	*	ns	ns	ns	ns	ns	ns	ns
CV (%)	2.6	6.8	8.4	6.9	7.9	6.8	6.9	7.8

Values in each column followed by the same letter (s) are not significantly different at 5% level. *Significant at 5% level; ns= Not significant.

Table 10. Changes in *β* carotene content (µg/100 g) of dragon fruit at different maturity stages

Maturity stage	Fresh	D-2	D-4	D-6	D-8	D-10	D-12	D-14
22 DAA	5.01 e	5.11 e	5.75 b	5.78 b	6.15 d	6.05 d	5.65 c	5.15 d
25 DAA	5.20 d	5.22 d	5.69 b	5.80 b	6.55 b	6.45 b	6.40 b	6.35 b
28 DAA	5.58 a	5.95 b	6.57 a	6.70 a	6.95 a	6.85 a	6.75 a	6.70 a
31 DAA	5.50 b	6.62 a	6.70 a	6.68 a	6.40 c	6.20 c	5.45 d	5.30 c
34 DAA	5.40 c	5.52 c	5.16 c	5.00 c	4.65 e	4.25 e	4.05 e	3.80 e
F-value	*	*	*	*	*	*	*	*
CV (%)	1.6	0.8	2.4	3.7	1.9	2.8	1.8	2.5

Values in each column followed by the same letter (s) are not significantly different at 5% level. *Significant at 5% level; ns= Not significant.

Sensory evaluation: Sensory data of fresh fruits and after 14 days of storage for dragon fruit based on visual appearance and organoleptic taste are presented in Table 11. Out of seven, the highest score of fresh fruit (6.80 ± 0.55) for overall sensory attributes was achieved by the fruits that harvested after 31 days of anthesis, which was significantly (P≤0.05) similar with fruits harvested after 34 days (6.60). While after 14 days of storage highest score (6.50 ± 0.55) achieved by the fruits of 28 DAA followed by 25 DAA (6.00 ± 0.45). At this stage of maturity, fruits were july, attained maximum flavour and taste with

attractive skin colour. Therefore, judges showed a significant preference for fruits that harvested after 31 DAA for fresh consumption and 28 DAA for storage which obtained mean acceptance scores between 'like very much' and 'like extremely' on the hedonic scale.

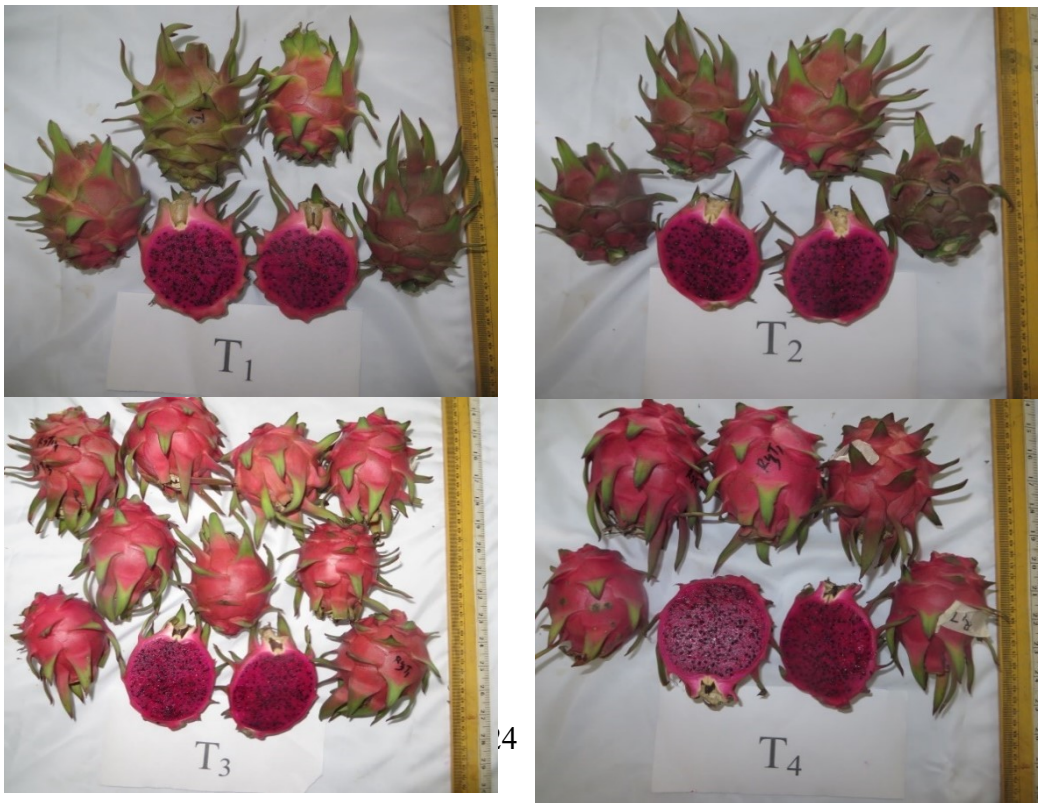
Table 11. Overall acceptability of fresh and after14 days of stored dragon fruit based on visual appearance and organoleptic taste harvested at different maturity stage.

Maturity stage	Overall sensory score (1-7) at fresh fruits	Overall sensory score (1-7) at fruits of 14 days after storage
22 DAA	4.80 ± 0.45 d	4.60 ± 0.35 c
25 DAA	5.00 ± 0.00 c	6.00 ± 0.45 b
28 DAA	6.20 ± 0.45 b	6.50 ± 0.55 a
31 DAA	6.80 ± 0.55 a	3.80 ± 0.00 d
34 DAA	6.60 ± 0.45 a	2.50 ± 0.45 e
F-value	*	*
CV (%)	7.2	4.6

Means within column with different letter are significantly different (P≤0.05)

Conclusion

Maturity of dragon fruit was determined by a combination of different attributes. In this study, TSS, ascorbic acid content, surface colour change, and firmness were found to be good indicators for dragon fruit maturity. Based on the results of the present study, dragon fruits (Var: BARI Dragon fruit-1) reached physiological maturity at 28 DAA. At this stage of maturity, fruit attained 9.10 cm length, 8.00 cm diameter, and 250 g in weight. Moreover, fruit consists 12.2% TSS, 78.45 mg/100g vitamin-C and 5.58 µg/100g *β* Carotene, which is a very important quality of fresh fruits. Besides, fruits have more shelf life (14 days of storage at ambient condition), found glossy, pleasant flavored, and also tasty at this stage.



12. Research highlight/findings:

- It was found that the off-season production of dragon fruits is made possible by manipulating the environment through artificial lightening using 100-watt incandescent bulb (normal bulb), 20-watt Light Emitting Diodes (LED) bulbs or 36-watt compact fluorescent lamps (CFL).
- The lightening time, from 16:00 to 22:00 can induce the dragon fruit plants to flower during short day-months of December - April. The bulbs are suspended at the center of the four pillars of dragon fruit plants five feet above the ground.
- The study revealed that irrespective of time of operation the longer cuttings showed superiority over shorter cuttings.
- Considering growth, flowering and fruiting were manifested from the plants treated with 250 % of the fertilizer dose applied in three to four split application.
- Dragon fruits reached physiological maturity at 28 DAA. At this stage, fruit attained 9.10 cm length, 8.00 cm diameter, and 250 g in weight. Moreover, fruit contained 12.2% TSS, 78.45 mg/100g of vitamin-C and 5.58 µg/100g of *β* Carotene.

B. Implementation Position

1. Procurement:

Description of equipment and capital items	PP Target		Achievement	
	Phy (#)	Fin (Tk)	Phy (#)	Fin (Tk)
(a) Office equipment				60000.00
Laptop	1	60000.00	1	25000.00
Digital camera	1	25000.00	1	
(b) Lab &field equipment				210000.00
IPS				90000.00
Programmable Electric	3	210000.00	3	25000.00
Timer				
Refractometer	5	90000.00	5	10000.00
Digital Slid Calipers	1	25000.00	1	
	1	10000.00	1	
(c) Furniture		24000.00		24000.00
Steel Almira	1		1	

2. Establishment/renovation facilities: N/A

Description of facilities	Newly established		Upgraded/refurbished		Remarks
	PP Target	Achievement	PP Target	Achievement	

3. Training/study tour/ seminar/workshop/conference organized: N/A

Description	Number of participant			Duration (Days)	Remarks
	Male	Female	Total		

C. Financial and physical progress

Fig in Tk

Items of expenditure	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
A. Contractual staff salary	172827.00	172827.00	172826.00	1.00	100.00	
B. Field research/lab expenses and supplies	743357.00	730215.00	730215.00	0.00	98.23	
C. Operating expenses	206990.00	202441.00	200530.00	1911.00	96.88	
D. Vehicle hire and fuel, oil & maintenance	103306.00	100498.00	100498.00	0.00	97.28	
E. Training/workshop/seminar etc.	0.00	0.00	0.00	0.00		
F. Publications and printing	94720.00	39318.00	12800.00	26518.00	13.51	
G. Miscellaneous	4800.00	4620.00	4620.00	0.00	96.25	
H. Capital expenses	444000.00	442386.00	442386.00	0.00	99.64	
Total	**1770000.00**	**1692305.00**	**1663875.00**	**28430.00**	**94.00**	

D. Achievement of Sub-project by objectives: (Tangible form)

Specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output (i.e. product obtained, visible, measurable)	Outcome (short term effect of the research)
1. To developed off season production technique of dragon fruit.	➢ Site selection, land preparation, field experimentation	Off-season production of dragon fruits is made possible by manipulating the environment through artificial lighting using 100-watt incandescent bulb (normal bulb), 20-watt Light Emitting Diode (LED) bulbs or 36-watt compact fluorescent lamps (CFL)	Following this techniques dragon fruit will be available round the year.
2. To standardize a production package of dragon fruit cultivation	➢ Field experimentation, Data collection and recording, Data analysis	• One year old 20 cm length is suitable for dragon fruit propagation. • 1350 g N, 787 g P, 625 g K) along with four split application at three months interval in each pit (pillar) along with 75 kg cow dung, 450 g Gypsum, 100 g Borax and 50 g $ZnSO_4$ per year is effective. • Dragon fruit at 28 DAA reached its proper maturity. At this stage fruit attained 9.10 cm length, 8.00 cm diameter, and 250 g in weight.	Adoption of modern technologies by the farmers will increase yield and total production of dragon fruit and fruit become available round the year.

E. Materials Development/Publication made under the Sub-project:

Publication	Number of publication		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology booklet	-	01	
Journal publication	01	-	
Information development	-	-	
Other publications, if any (tv clip)	-	01	Channel I

F. Technology/Knowledge generation/Policy Support (as applied):

i. Generation of technology (Commodity & Non-commodity)

Dragon fruit production can be increased and available round the year by manipulating the day length by lightening. Farmers will be benefitted by producing year round production technology.

ii. **Generation of new knowledge that help in developing more technology in future**

Knowledge on environmental manipulation for year round productivity, propagation, fertilizer management and maturity indices of high value crops like dragon fruit may help to developing more technology in other crops in future.

iii. Technology transferred that help increased agricultural productivity and farmers' income

Adoption of modern technology package by the farmers will increase yield and total production of dragon fruit.

iv. Policy Support

Technological support, training support, provision of subsidy, soft loans, etc. may encourage farmers to grow dragon fruit in Bangladesh

G. Information regarding Desk and Field Monitoring

i) Desk Monitoring [description & output of consultation meeting, monitoring workshops/seminars etc.):

Description	Output
Program Planning Workshop	Detailed research program was discussed with BARI, BARC, DAE, BADC and NGOs
Review Workshop	Detailed research program and report was discussed and finalized through regional, internal and central research workshop of HRC and BARI
Personal Contact	Regularly monitor the activities from the desk by phone, email etc.

ii) Field Monitoring (time & No. of visit, Team visit and output):

Time	No. of visit	Team visit	Output
January 2018	3	DAE, BADC, NGOs	• The team expressed their satisfaction to the experimental sites
October 2018 to September 2019	7	Farmers	• More than 250 farmers under different motivational tour and visited the experimental sites
December 2017 February 2018 April 2018 November 2018	4	Director (Research), Research monitoring team and Director SS with associates	• Monitoring team made by Director (Res), Director (SS) and research monitoring team satisfied on the research progress

H. Lesson Learned/Challenges (if any)

i) For successful and timely completion of any sub-project, timely release of fund needs to be ensured
ii) To achieve any success/visible output in any agricultural sub-project, minimum time duration of the project should be 3 years

I. Challenges (if any)

- Excessive rainfall just after initiated the experiment at December, 2017
- Interrupted and in-sufficient power supply at Joydebpur, Gazipur and Raikhali, Rangamati hampered the experimental result at that two sites.

Signature of the Principal Investigator
Date ……..
Seal

Counter signature of the Head of the organization/authorized representative
Date ……..
Seal

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Appendices

Appendix-I: Analytical data of soil sample of RHRS of BARI, Shibpur,Narsingdi

Lab. No.	Sample No.	pH	O.M. %	Ca	Mg	K	Total N %	P	S	B	Cu	Fe	Mn	Zn
				meq/100 ml				$\mu g/ml$						
5420	2 (East)	6.8	0.34	6.3	2.2	.070	0.018	44.0	25	.10	2.0	45	3.6	0.80
Critical level		**-**	**-**	**2.0**	**0.5**	**0.12**	**-**	**7.0**	**10**	**0.2**	**0.2**	**4.0**	**1.0**	**0.6**

Source: Bangladesh Agricultural Research Institute, Division of soil Science, Joydebpur, Gazipur.

Appendix-II: Monthly meteorological data for the experimental period (October 2017- September 2018) of RHRS, Bangladesh Agricultural Research Institute, Shibpur, Narsingdi.

Month	Temperature		Relative Humidity (%)
	Mean max.	Mean min.	
October '17	32.2	23.1	84.2
November '17	30.3	19.2	81.2
December '17	26.2	13.5	79.8
January '18	23.2	9.5	79.2
February '18	28.2	12.3	70.1
March '18	32.5	18.1	72.0
April '18	33.8	21.8	77.5
May '18	35.1	23.2	81.1
June '18	35.1	26.3	83.1
July '18	34.4	26.7	82.7
August '18	32.4	26.2	84.4
September '18	32.7	26.1	81.7