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Flowering Response of a Red Pitaya Germplasm Collection to Lighting Addition

Dinh-Ha Tran, Chung-Ruey Yen, Yu-Kuang H. Chen

***Abstract*—**A collection of thirty cultivars/clones of a red pitaya was used to investigate flowering response to lighting supplementation in the winter season of 2013-2014 in southern Taiwan. The night-breaking treatment was conducted during the period of 10 Oct. 2013 to 5 Mar. 2014 with 4-continuous hours (22.00 – 02.00 hrs) of additional lighting daily using incandescent bulbs (100W). Among cultivars and clones tested, twenty-three genotypes, most belonging to the red-magenta flesh type, were found to have positively flowering response to the lighting treatment. The duration of night-breaking treatment for successful flowering initiation varied from 33- 48 days. The lighting-sensitive genotypes bore 1-2 flowering flushes. Floral and fruiting stages took 21-26 and 46-59 days, respectively. Among sixteen fruiting genotypes, the highest fruit set rates were found in Damao 9, D_4, D_{13}, Chaozou large, Chaozhou 5, Small Nick and F_{22}. Five cultivars and clones (Orejona, D_4, Chaozhou large, Chaozhou 5 and Small Nick) produced fruits with an average weight of more than 300 g per fruit which were higher than those of the fruits formed in the summer of 2013. Fruits produced during off-season containing total soluble solids (TSS) from 17.5 to 20.7°Brix, which were higher than those produced in-season.

***Keywords*—**Flowering response, long-day plant, night-breaking treatment, off-season production, pitaya.

I. Introduction

DRAGON fruit (*Hylocereus* spp.), also known as pitaya or pitahaya, is increasingly gaining interest in many countries as a result of its tolerance to arid environments, resistance to pathogens, flesh acceptability and rising demand in the world market [14]-[16], [18]. Owing to the flesh being mildly sweet, juicy, with a delicate aroma and having high nutritive and medicinal values, pitaya fruit is considered a favored vegetable-fruit healthy food [12]. Pitaya have been introduced to Taiwan in recent decades and has become a popular fruit crop. Most commonly grown varieties have red peel with white flesh (*Hylocereus undatus*) or red-purple flesh (*Hylocereus* sp.). Under natural cultivation conditions in Taiwan, pitayas have been considered as a long-day plant which produces fruits in summer and fall [6], [9], [20], [24]. Breeding for winter-bearing cultivars as well as developing methods to regulate flowering to produce winter crops would benefit the pitaya industry in Taiwan [2], [7], [8], [23]. Breeding for winter-bearing cultivars as well as developing methods to regulate flowering to produce winter crops would benefit the pitaya industry in Taiwan [2], [7], [8], [23].

Some research on induction of off-season pitaya fruit in some tropical regions such as Taiwan [9], [20], [23], Vietnam [5] and Thailand [19] have demonstrated that flowering stimulation may be conducted with the help of lighting supplementation and/or growth stimulators. The lighting treatment has showed better results than the plant growth regulator (PGR) method. While PGR method produced less stable flowering and fruiting, lighting treatment resulted in higher flower and fruit uniformity. Thus, the lighting treatment has been commonly applied in pitaya production on commercial scales. Based on previous studies of pitaya off-season production by breaking the dark period in Taiwan [9], [20], [23], a four-hour lighting treatment with 75-100 W Tungsten filament (incandescent) bulbs from 22:00 pm to 2:00 am has been indicated as the most effective treatment.

To implement pitaya breeding programs, a pitaya germplasm collection of different clones and culivars is maintained at the Tropical Fruit Orchard at National Pingtung University of Science and Technology (NPUST), Taiwan. The main goal of this study was to verify flowering response of these collected pitaya materials to lighting induction during the winter season. In addition, the flowering and fruit characteristics of some genotypes were determined and compared with those produced during the summer season. The effects of the major environmental factors such as day length and temperature on flowering and fruiting were elucidated.

II. Material and Methods

A. Plant Materials and Study Site

A collection of thirty different red peel pitaya clones and cultivars around ten-years old at the NPUST Orchard in Pingtung, southern Taiwan (lat. 22 °70'N, long. 120 ° 55'E) used in this study is listed in Table I. Each clone or cultivar consists of 1-2 plants intercropped with other clones and/or cultivars within rows. The pitaya plants were grown on concrete posts with 1.5 m height and spacings of 2 m between plants and 3 m between rows.

Among thirty clones and cultivars tested, only three genotypes with white flesh have had their species confirmed in earlier study or by judging from their breeding system and morphology. However, the rest of the clones and cultivars were untraceable. To our knowledge, most magenta flesh clones and cultivars collected in Taiwan were hybrids (*Hylocereus* sp.) between *H. undatus* and *H. polyrhizus*. The flesh color, breeding system and origin of each clone or cultivar are indicated in Table I.

Dinh-Ha Tran is with Department of Plant Industry, National Pingtung University of Science and Technology, Pingtung 921, Taiwan (Corresponding author, phone : +886-934-155-059, e-mail: tdha.tuaf@gmail.com).

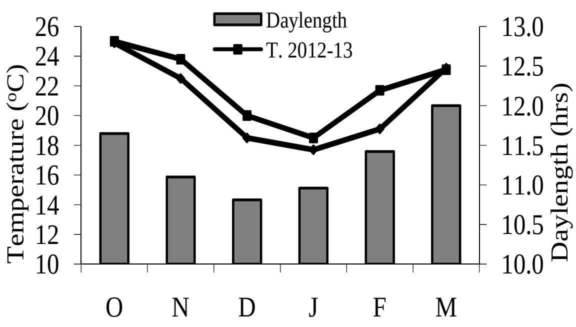
Chung-Ruey Yen and Yu-Kuang H.Chen are with Department of Plant Industry, National Pingtung University of Science and Technology, Pingtung 921, Taiwan (e-mail: yencr@mail.npust.edu.tw, ykchen@mail.npust.edu.tw).

TABLE I
THE PITAYA MATERIALS USED IN THIS STUDY AND THEIR FLOWERING RESPONSE TO LIGHTING TREATMENT IN SOUTHERN TAIWAN

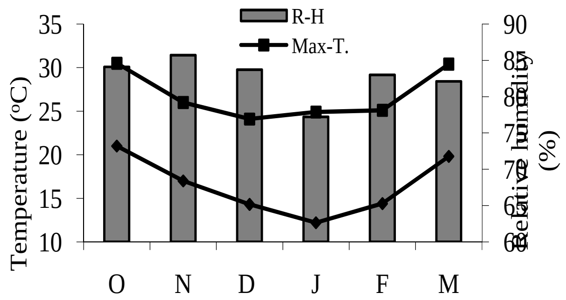
Cultivar/clone	Species	Flesh color	Breeding system	Origin
VN-White	*H. undatus*	white	SC	Vietnam
Chuchi luu	*H. undatus*	white	SC	Taiwan
P Long	*H. undatus*	white	SC	Taiwan
Pink	*Hylocereus* sp.	light pink	SI	Taiwan
WE 23	*Hylocereus* sp.	light pink	SI	Taiwan
Orejona	*Hylocereus* sp.	red	SI	Central America
Criollo	*Hylocereus* sp.	red	SI	Central America
Malagu	*Hylocereus* sp.	red	SI	Central America
Cebra	*Hylocereus* sp.	red	SI	Central America
Lisa	*Hylocereus* sp.	red	SI	Central America
Rosa	*Hylocereus* sp.	red	SI	Central America
Damao 9	*Hylocereus* sp.	red	SI	Taiwan
Jhubei 1	*Hylocereus* sp.	red	SI	Taiwan
Jhubei 3	*Hylocereus* sp.	red	SI	Taiwan
D_2	*Hylocereus* sp.	magenta	SI	Taiwan
D_4	*Hylocereus* sp.	magenta	SC	Taiwan
D_{11}	*Hylocereus* sp.	magenta	SI	Taiwan
D_{13}	*Hylocereus* sp.	magenta	SI	Taiwan
D_{15}	*Hylocereus* sp.	magenta	SI	Taiwan
D_{18}	*Hylocereus* sp.	magenta	SI	Taiwan
D_{22}	*Hylocereus* sp.	magenta	SI	Taiwan
Chaozhou large	*Hylocereus* sp.	magenta	P-SC	Taiwan
Chaozhou 5	*Hylocereus* sp.	magenta	P-SC	Taiwan
Small Nick	*Hylocereus* sp.	magenta	SI	Taiwan
F_4	*Hylocereus* sp.	magenta	SC	Taiwan
F_{11}	*Hylocereus* sp.	magenta	SI	Taiwan
F_{13}	*Hylocereus* sp.	magenta	SI	Taiwan
F_{17}	*Hylocereus* sp.	magenta	SI	Taiwan
F_{18}	*Hylocereus* sp.	magenta	SI	Taiwan
F_{22}	*Hylocereus* sp.	magenta	SI	Taiwan

SC, self-compatible with70-100% fruit set after selfing; P-SC, partially self-compatible with 40-70% fruit set after selfing; SI, self-incompatible with 0-10% fruit set after selfing. Selfing means hand self- pollination.

The temperature and day length data obtained from a local meteorological station are presented in Figs. 1 (a), (b). The daily average temperatures during the experimental period of October 2013 to March 2014 were from 17.7°C in January to 24.9°C in October, which were lower than the same duration of 2012–2013. The natural day length ranged between a minimum of 10.8 hours in December to a maximum of 12.0 hours in March (Fig. 1 (a)). Daily average maximum temperatures varying from 24.1°C in December to 30.5°C in October were much higher than minimum temperatures ranging between 12.2°C in January and 21.0°C in October (Fig. 1 (b)). Relative humidity ranged from 77.0 % in January to 86.0 % in November.



(a)



(b)

Fig. 1 Climatic data for the four study sites (Pingtung, Taiwan) (a) The monthly average daylength and temperature (T.) from Oct. 2012 – Mar. 2013 and from Oct. 2013 – Mar. 2014. (b) The monthly average maximum (Max) and minimum temperature (Min), and relative humidity (R-H) during the experimental period from Oct. 2013 – Mar. 2014

B. Methods and Measurements

The night-breaking treatment was conducted during the period from Oct. 10, 2013 to Mar. 5, 2014. The plants were provided 4 hrs (22:00 pm – 02:00 am) of additional light daily using incandescent bulbs (TC115 V100W; China Electric Mfg. Co., Taiwan). The bulbs were placed 30 cm above the plants and one bulb was used for each plant.

Parameters of flowering response to lighting treatment were recorded. The number of days from the start of the lighting treatment to first bud emergence was counted. The times at which all floral buds of each clone or cultivar reached different floral and fruit stages were recorded. The number of flowers and fruits, flowering cycles/flushes per plant was also recorded. All mature fruits from each clone or cultivar were harvested and fruit characteristics were examined. The fruit diameter was measured at two axes of the midsection of the fruit. Fruit length was measured from the part attached to the petiole to the base of the fruit. Peel thickness was determined at the equatorial point of fruit with a digital caliper. Fruit weight was measured with an electronic balance and the edible portion of fruit was calculated using the following formula: Edible portion (%) = (Pulp weight / fruit weight) × 100. Total soluble solids (TSS) content was measured using a hand refractometer (model PAL-1, Atago, Tokyo, Japan). Fruit flesh was squeezed from a sample in the middle of freshly cut fruit and the result was expressed as ^{o}Brix.

The characteristics of fruits resulting from the lighting treatment in the winter 2013-2014 were compared with those produced in the summer 2013.

C. Statistical Analysis

All parameter values were represented by the arithmetic means using excel software 2007.

III. Results

A. Flowering Induction and Fruit Formation by Lighting Treatment

The flowering response to the lighting treatment of the pitaya cultivars and clones tested is indicated in Table II. Among the thirty cultivars and clones investigated, twenty-three genotypes were positively sensitive to additional lighting in the winter season. The duration of the night-breaking treatment for successful flower initiation varied depending on the genotypes, which ranged from 33 - 48 days. Two domestic materials, Chaozhou 5 and Small Nick, showed the earliest flowering induction resulting from the night-breaking.

Floral and fruit stages in the winter season took 21-26 and 46-59 days, respectively. The lighting-sensitive genotypes bore 1-2 flowering flushes with various numbers of flowers (1- 15). The higher fruit set rates were found in Damao 9, D_4, D_{13}, Chaozou large, Chaozhou 5, Small Nick and F_{22}. The other clones and cultivars could not produce fruits or set only a few fruits.

TABLE II
Flowering-Sensitivity, Flowering and Fruiting Induction by Lighting Treatment (Starting Oct. 10, 20130) of 30 Red Peeled Pitaya Cultivars and Clones

Cultivar/clone	Flowering sensitivity to lighting*	Lighting days for flower initiation	Flowering duration (day)	Number of flowering cycles	Number of flowers/ plant	Number of fruits/ plant	Fruiting duration (day)
VN- White	−	-	-	-	-	-	-
Chuchi luu	−	-	-	-	-	-	-
P Long	−	-	-	-	-	-	-
Pink	−	-	-	-	-	-	-
WE 23	+	39	25	2	10	0	-
Orejona	+	48	24	1	1	1	53
Criollo	+	48	25	1	2	0	-
Malagu	+	48	25	1	4	0	-
Cebra	+	48	24	1	3	0	-
Lisa	+	36	26	2	5	2	46
Rosa	+	35	25	1	2	1	48
Damao 9	+	38	26	2	5	3	54
Jhubei 1	+	42	22	2	2	1	57
Jhubei 3	+	42	22	2	4	1	59
D_2	+	39	26	2	4	0	-
D_4	+	43	21	1	3	2	52
D_{11}	+	48	24	1	2	0	-
D_{13}	+	43	22	2	6	5	55
D_{15}	+	43	21	2	15	1	58
D_{18}	+	39	23	2	9	1	59
D_{22}	+	42	24	1	6	4	55
Chaozhou large	+	40	21	2	8	6	55
Chaozhou 5	+	33	20	2	5	3	54
Small Nick	+	33	24	2	4	3	53
F_4	−	-	-	-	-	-	-
F_{11}	−	-	-	-	-	-	-
F_{13}	−	-	-	-	-	-	-
F_{17}	+	44	20	1	1	1	57
F_{18}	+	43	20	2	5	0	-
F_{22}	+	44	21	2	5	3	59

* + or − indicate positive or negative flowering response to lighting treatment
- no data

TABLE III
COMPARISON OF FRUIT CHARACTERISTICS BETWEEN FRUITS OBTAINED FROM NATURAL PRODUCTION IN SUMMER 2013 AND THOSE FROM THE LIGHTING TREATMENT IN WINTER 2013-2014 IN 16 PITAYA CULTIVARS AND CLONES

Cultivar/clone	Fruit weight (g)		Peel thickness (mm)		Edible rate (%)		TSS content (°Brix)	
	In-season*	Off-season	In-season	Off-season	In-season	Off-season	In-season	Off-season
Orejona	196.6	331.4	4.9	6.1	49.9	53.0	18.1	18.8
Lisa	297.2	289.5	4.8	3.9	65.2	61.0	17.1	17.5
Rosa	251.7	472.0	4.6	4.6	60.7	66.8	16.2	17.6
Damao 9	251.5	147.9	3.7	4.2	60.4	49.7	18.4	17.8
Jhubei 1	265.3	206.6	3.9	5.6	60.8	51.6	18.2	19.4
Jhubei 3	176.8	277.2	3.9	4.2	55.6	70.6	16.1	20.7
D_4	340.8	568.0	2.7	3.8	73.7	77.7	18.3	19.7
D_{13}	214.7	179.8	4.0	4.3	56.6	53.8	18.6	18.8
D_{15}	179.1	168.7	3.6	3.3	54.6	61.7	17.2	18.8
D_{18}	186.2	186.9	3.9	3.5	52.0	57.2	16.2	18.4
D_{22}	264.0	242.0	3.2	4.0	63.4	59.2	19.2	19.4
Chaozhou large	421.2	541.8	3.5	4.3	66.7	66.8	18.8	20.0
Chaozhou 5	314.1	329.0	4.0	4.0	64.2	60.8	17.7	18.3
Small Nick	288.2	350.5	3.6	3.8	57.9	62.4	18.1	20.0
F_{17}	359.7	142.2	2.5	3.3	72.5	56.0	17.3	18.9
F_{22}	319.1	165.0	3.5	3.6	61.7	61.2	20.1	20.6

*In-season data from our research in 2013

B. Fruit Characteristics in Off-season

Among the twenty-three genotypes which had flowers induced by lighting treatment, sixteen of them set and provided mature fruits. Some quality parameters of fruits produced during the winter 2013 - 2014 (off-season) and produced during the summer 2013 (in-season) are presented in Table III. Fruit weight produced during off-season widely varied from 142.2 to 568.0 g/fruit among different genotypes. Among sixteen fruiting genotypes, six cultivars and clones (Orejona, Rosa, D_4, Chaozhou large, Chaozhou 5 and Small Nick) produced fruits with an average weight of more than 300 g/fruit and were also heavier than their fruits produced in the summer of 2013 (Table III). Fruit peel thickness in the off-season ranged from 3.3 to 6.1 mm and most were thicker than those from the same genotypes in-season with some exceptions. In the winter season, the edible fruit portion accounted for 49.7 to 77.7 percent of fruit weight. The higher edible rates were found in fruits with a higher fruit weight. Fruits produced during the off-season had TSS content ranging from 17.5 to 20.7 °Brix which were higher than those produced in-season except for fruits from Damao 9.

IV. DISCUSSION

Pitaya has been confirmed to be a long-day plant, requiring a longer day length than a certain critical day length to flower [9], [18], [23], [24]. Observation on all red pitaya plant materials tested grown under natural conditions from October 2012 to March 2013 indicated that they did not flower. The lighting treatment was then carried out at the same time in 2013-2014 when plants were sprouting in conditions when day length had decreased to less than the 12 h-critical day length [9] and temperature also reduced, slightly lower than that in the winter of 2012-2013 (Fig. 1 (a)). Thus, it is confirmed that flowering induction during our experimental duration (Table II) had resulted from the night-breaking treatment. The flowering-sensitivity to artificial lighting was variant among genotypes. Most red flesh genotypes exhibited a positive flowering response to additional lighting with differences in the time of night-breaking for floral initiation and the number of flowers induced, while white-fleshed types and close relatives did not respond to the lighting treatment. The sensitivity to flowering with a lighting treatment of red flesh types was also found in hybrids [9], but needed a shorter night-breaking duration (four weeks) for flower initiation. This variation between our study and the previous study may be mainly attributed to the different genotypes and ages of plant materials. In addition, other research [3], [5], [19], [23] had reported that artificial lighting addition was applicable to induce flowering and off-season production for Vietnam pitaya (*H. undatus*). This is contradictory to what we have found for the same species and its close relatives in the present study. This difference may be due to different temperatures among the experimental locations and conditions of the studies. According to [1], pitahaya (*H. undatus*) was adapted to mean temperatures of 21 to 29°C. In addition, [10] and [11] concluded that neither day length nor temperature alone could induce evocation and formation of flower buds in different pitaya species. For example, pitaya plants were unable to alter flowering by extending the day length between March and July in Israel due to the inhibition of low temperatures (16/22°C), even under long-day conditions. Occurrence of temperatures lower than 20°C from Nov. to Feb (Fig. 1 (b)) may be one of the causes of the interference/interruption of flower induction in *H. undatus* species and its close relatives. In contrast, growing in tropical regions such as southern Vietnam [5], southern Thailand [19], or southern Taiwan with plastic covering [3], the higher temperatures in late fall and winter seasons were more adequate for this species to induce flowering. The results and analyses above may lead to postulation that red flesh species require lower temperatures for flower initiation than white-fleshed species. This postulation is consistent with [20], who affirmed that lighting treatment in October forced the fruit in December and was more effective for red pulp varieties than white pulp varieties. The time from anthesis to mature harvest stage depended on temperature [17]. Flowering and fruiting stages in the off-season (Table II) were much longer than that in-season (15-19 and 31-32 days, respectively) [21]. These data are in correspondence with the results of off-season fruit production in Vietnam [5] and Thailand [19]. It is obvious that the low temperatures in winter season (Figs. 1 (a), (b)) extended the reproductive processes.

Regarding fruit weight in cacti, [22] found that it was positively correlated with seed numbers that depended on the efficiency of pollination. In addition, [24] noted that the fruits produced during the cool season in Taiwan were more desirable in the market than fruits from summer because the off-season fruits were larger and sweeter. These conclusions are in agreement with our results that showed fruits produced off-season were larger in six cultivars and clones, and sweeter in most cultivars and clones as compared with those formed in-season (Table III). Cooler temperatures at the earlier fruit growth stages was considered favorable for cell division and thus for the formation of a larger fruit size [4], [13]. Large differences between day and night temperatures (Fig. 1 (b)) may achieve higher photosynthetic accumulation and sweeter fruit. For example, the optimal day/night air temperatures for total daily net CO_2 uptake by *Hylocereus undatus* were at 30/20°C [18]. However, some genotypes produced fruits in the off-season that were smaller than fruits produced in-season (Table III). This may due to the fact that in the off-season there were fewer flowers induced with different blooming times and a decrease of pollinator activity at lower temperatures, which led to a lack of pollen sources or inadequate pollen amounts for self-incompatible genotypes to set fruit by out-crossing.

V. Conclusion

The flowering induction by artificial lighting in off-season in southern Taiwan was different among pitaya genotypes and also was affected by temperature. Red-fleshed pitaya showed more application to induce flowers by a night-breaking treatment than white-fleshed pitaya which required lower temperatures. The time of lighting treatment (starting October) for successful flower initiation and formation varied from 33 - 48 days. Lighting-sensitive pitaya genotypes bore 1-2 flowering flushes and it took in total 72–82 days for flowering stages and fruit growth. Off-season fruits in several pitaya genotypes were larger than in-season fruits. In addition, fruits produced in the off-season contained higher TSS content than those produced in-season.

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References

[1] G. Barbeau. "La pitahaya rouge, un nouveau fruit exotique". Fruits, 45, pp 141-147. 1990.

[2] T. Chang. "Yield and quality of pitaya (*Hylocereus undatus* Britt. & Rose) as affected by fruiting regulation. Master thesis, National Chung Hsing University, Taiwan. 2003.

[3] J. Y. Fan. "Studies on forcing culture and storage in pitaya (*Hylocereus* spp.)". Master thesis. Pingtung University of Science and Technology. Taiwan. 2010.

[4] E. Greybe, O. Bergh and D. I. Ferrira. "Fruit growth and cell multiplication of Royal Gala apples as a function of temperature". Apple Plant Science, 12, pp 10–14. 1998.

[5] N. V. Hoa, N. H. Hoang, M. C. John and N. M. Chau. "Developing GAP systems for dragon fruit producers and exporters in Binh Thuan and Tien Giang provinces". Proceeding of Dragon fruit workshop. Held on 21 July. 2008 in Binh Thuan, Vietnam. (In Vietnamese).

[6] W. Hsu. "Investigations on culture, growth habits and phenology in pitaya (*Hylocereus* spp.). Master thesis, National Taiwan University, Taiwan. 2004.

[7] Y. L. Jiang. "Classification, flowering and fruiting characteristics, and pruning of climbing cactus". Master thesis, National Taiwan University, Taiwan. 2005.

[8] Y. L. Jiang, T. S. Lin and C. L. Lee. "Phenology, canopy composition and fruit quality of yellow pitaya in tropical Taiwan". HortScience, 46(11), pp 1497–1502. 2011.

[9] Y. L. Jiang, Y. Y. Liao, T. S. Lin**,** C. L. Lee, C. R. Yen and W. J. Yang. "The photoperiod-regulated bud formation of red Pitaya (*Hylocereus* sp.). HortScience, 47(8), pp 1063-1067. 2012.

[10] A. Khaimov and Y. Mizrahi. "Effects of day-length, radiation, flower thinning and growth regulators on flowering of the vine cacti *Hylocereus undatus* and *Selenicereus megalanthus*". Journal of Horticultural Science & Biotechnology, 81 (3), pp 465–470. 2006.

[11] A. Khaimov, O. Novák, M. Strnad and Y. Mizrahi. "The role of endogenous cytokinins and environmental factors in flowering in the vine cactus *Hylocereus undatus*". Israel Journal of Plant Sciences, 60, pp 371–383. 2012.

[12] F. Le Bellec, F. Vaillant and E. Imbert, "Pitahaya (*Hylocereus* spp.): A new fruit crop, a market with a future", Fruits, 61(4), pp 237–250. 2006.

[13] J. G. Li, H. B. Huang and X. M. Huang. "Differential fruit sizing of Feizixiao litchi fruit from early and late bloom as affected by temperature regimes". Journal of Fruit Science, 21, pp 37–41. 2004.

[14] Y. Mizrahi and A. Nerd, "Climbing and columnar cacti, New arid land fruit crops", In: Perspective in new crops and new uses, J. Janick, (Eds.), Alexandria: ASHS Press, 1999, pp 358-366.

[15] Y. Mizrahi, A. Nerd, and P. S. Nobel. "Cacti as crops". Hort. Rev., 18, pp 291–391. 1997.

[16] Y. Mizrahi, A. Nerd and Y. Sitrit. "New fruit for arid climates", In: Trends in new crops and new uses. J. Janick, (Eds.), Alexandria: ASHS Press, 2002, pp 378–384.

[17] A. Nerd, F. Gutman and Y. Mizrahi. "Ripening and postharvest behaviour of fruits of two *Hylocereus* species (Cactaceae)". Postharvest Biology and Technology, 17, pp 39–45. 1999.

[18] P. S. Nobel and E. De La Barrera, "CO_2 Uptake by the Cultivated Hemiepiphytic Cactus, *Hylocereus undatus*", Annals Applied of Biology, 144 (1), pp 1-8. 2004.

[19] . P. Saradhuldhat, K. Kaewsongsang and K. Suvittawat. "Induced Off-Season flowering by supplemented fluorescent light in dragon fruit (*Hylocereus undatus*)". Journal of International Society for Southeast Asian Agricultural Sciences, 15(1), pp 231-258. 2009.

[20] H. Su. "Effects of Photoperiod and Pruning on Off-Season Production in Piataya (*Hylocereus* spp)". Master thesis, National Pingtung University of Science and Technology, Taiwan. 2005.

[21] D. H. Tran and C. R. Yen. "Morphological characteristics and pollination requirement in red pitaya (*Hylocereus* spp.)". International Journal of Agricultural, Biosystems Science and Engineering, 8 (3), pp 6-10. 2014.

[22] J. Weiss, A. Nerd and Y. Mizrahi, "Flowering behavior and pollination requirements in climbing cacti with fruit crop potential", HortScience, 29(12), pp 1487–1492. 1994.

[23] C. R. Yen and F. R. Chang. Forcing pitaya (*Hylocereus undatus* Britt. & Rose) by chemicals and controlled daylength and temperature. Proceeding of the symposium on enhancing competitiveness of fruit industry. Taichung district agricultural improvement station, Taiwan, pp 163–170. 1997. (Chinese with English summary).

[24] F. Zee, C. R. Yen and M. Nishina. Pitaya (Dragon Fruit, Strawberry Pear). Fruits and Nuts, 9, pp 1-3. 2004.