Asian Journal of Advances in Agricultural Research

7(3): 1-8, 2018; Article no.AJAAR.43616
ISSN: 2456-8864

Flowering Phenology and Mating System of a Red Skin Pitaya (*Hylocereus* spp.) Germplasm Collection in Taiwan

Tran Dinh Ha[1*], Le T. Kieu Oanh[1] and Chung-Ruey Yen[2]

[1]Department of Agronomy, Thai Nguyen University of Agriculture and Forestry, Quyet Thang Commune, Thai Nguyen City, Vietnam.
[2]Department of Plant Industry, National Pingtung University of Science and Technology, 1 Shuefu Road, Neipu, Pingtung, Taiwan.

Authors' contributions

This work was carried out in collaboration between all authors. Author TDH designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author LTKO managed the analyses of the study. Author CRY managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJAAR/2018/43616
Editor(s):
(1) Dr. Oguz Dolgun, Associate professor, Department of Plant and Animal Production, Adnan Menderes University, Sultanhisar Vocational College, Turkey.
Reviewers:
(1) Raúl Leonel Grijalva-Contreras, Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias, México.
(2) Florin Sala, Banat University of Agricultural Sciences and Veterinary Medicine, Romania.
(3) Oluwatoyin Sunday Osekita, Adekunle Ajasin University, Nigeria.
Complete Peer review history: http://prh.sdiarticle3.com/review-history/26161

Short Research Article

Received 3rd June 2018
Accepted 20th August 2018
Published 10th September 2018

ABSTRACT

Aims: To Investigate flowering phenology and mating systems of 30 red skin pitaya genotypes
Study Design: Around ten-years-old pitaya genotypes were used in this study. The pitaya plants were grown on concrete posts/pillars with 1.5 m height and spacing of 2 m between plants and 3 m between rows. One-two plants were used for intercropping with each other.
Place and Duration of Study: At the NPUST's Orchard between May and December 2014.
Methodology: From 1 to 2 plants for each genotype was verified for flowering characteristics, fruit set and fruit weight. Hand self-pollination and hand cross-pollination method was applied. Fruit weights were compared using Duncan's multiple range test at a significance level of $P \leq 0.05$.
Results: The natural flowering season of the pitayas occur from June to October with early comings in higher temperatures. Mostly red or magenta pulp pitayas have genotypes for a longer

---

*Corresponding author: Email: trandinhha@tuaf.edu.vn;

flowering season than white flesh ones. A number of flowering flushes and flowers/season/plant highly varies with 3 – 6 waves and 9 - 40 flowers. The floral and fruit stages spend 14 – 18 days and 27 – 33 days, respectively. Full self-compatibility (F-SC) in 3 white flesh and 3 magenta flesh, partial self-compatibility in 2 magenta flesh, and complete self-incompatibility (C-SI) in 22 red or magenta flesh was found. Hand cross-pollination gave high fruit set percentages (72.7 – 100%) in all and larger fruits than hand self-pollination in almost all genotypes except for VN-White producing smaller fruits that performed strong SC mechanism.

Conclusion: A diversity in reproductive biology was found in the pitaya collection. VN-White, Chuchi Luu, D_4, Chaozhou large, Chaozhou 5 and F_4 that exhibited good reproductive characteristics could be further multiplicated for commercial cultivation and the one which have extended flowering season should be induced for off-season fruits. The breeding system types of cultivars help to design desired planting system orchards that achieve the most effective fruit production.

Keywords: Red pitayas; flowering phenology; mating systems; fruit set; pollination.

1. INTRODUCTION

Dragon fruit (*Hylocereus* spp.), also known as pitaya, 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 [1,2,3]. Therefore, it has been drawn great interests to research. Regarding reproductive biology, some studies have reported that flowering season, number of flowering flushes and flowers/season or year varies in different species and growing locations [4-11]. Breeding systems show a wide variety of compatibility systems in pitaya cultivars or species. Most of *H. undatus* genotypes have been reported as self-compatible, setting fruit with self-pollination. In contrast, *H. polyrhizus* and *H. costaricensis* and a few *H. undatus* species have been found to be self-incompatible, requiring cross-pollination to set fruit [12-16,10]. The self-compatible system is one of the most important targets in breeding programs due to the ability to grow a self-compatible cultivar alone without the need of hand-cross pollination as a self-incompatible cultivar [12,17,14,15,18,10]. For this goal and improving fruit traits, breeding programs have been conducted by using a collection of taxonomical identification, hybridisation and autotetraploidisation in vine cactus species [12,17,19,13,20,21,18,22].

Pitaya has 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.) [4]. In Taiwan, under the natural cultivation conditions, pitayas have been considered as a long-day plant which produces fruits in summer and fall [23,4,24,25]. To implement pitaya breeding programs, a collection of 30 different genotypes is maintained at the Tropical Fruit Orchard at NPUST, Taiwan. The main goal of this study was to verify reproductive biology: flowering phenology, mating systems of the 30 different pitaya genotypes.

2. MATERIALS AND METHODS

2.1 Plant Materials and Study Site

Around ten-years-old 30 different pitaya genotypes were collected and grown at the National Pingtung University of Science and Technology's Orchard (NPUST Orchard) in Pingtung, Southern Taiwan (lat. 22°40′N; long. 120°59′E; alt. 71 m, amount of rainfall in experiment period: 2,036.5 mm) (Table 1). The pitaya plants were grown on concrete posts/pillars with 1.5 m height and spacing of 2 m between plants and 3 m between rows. From 1 – 2 plants were used for studying each genotype. The experiments were carried out from May to December 2014.

Among 30 genotypes tested, only one (VN-White) with white flesh has had its species confirmed in the earlier study [26]. Based on the plant morphology, the rest of the 30 genotypes were estimated to belong or close to 2 genera, including *H. undatus* or *H. polyrhizus* and hybrid type (*Hylocereus* sp.). To the best of our knowledge, most magenta flesh genotypes collected in Taiwan were hybrids (*Hylocereus* sp.) between *H. undatus* and *H. polyrhizus*. The name, estimated species, flesh colour and origin of each genotype are presented in Table 1.

Table 1. The name, estimated species, flesh colour and origin of 30 pitaya genotypes used in this study

Genotype name	Estimated species	Flesh color	Origin
VN-White	*H. undatus*	white	Vietnam
Chuchi Luu	*H. undatus*	white	Taiwan
P Long	*H. undatus*	white	Taiwan
Pink	Close *H. undatus*	light pink	Taiwan
WE 23	Close *H. undatus*	light pink	Taiwan
Orejona	*H. polyrhizu*s	red	Central America
Criollo	*H. polyrhizu*s	red	Central America
Malagu	*H. polyrhizu*s	red	Central America
Cebra	*H. polyrhizu*s	red	Central America
Lisa	*H. polyrhizu*s	red	Central America
Rosa	*H. polyrhizu*s	red	Central America
Damao 9	Close *H. polyrhizu*s	red	Taiwan
Jhubei 1	Close *H. polyrhizu*s	red	Taiwan
Jhubei 3	Close *H. polyrhizu*s	red	Taiwan
D_2	*Hylocereus* sp.	magenta	Taiwan
D_4	*Hylocereus* sp.	magenta	Taiwan
D_{11}	*Hylocereus* sp.	magenta	Taiwan
D_{13}	*Hylocereus* sp.	magenta	Taiwan
D_{15}	*Hylocereus* sp.	magenta	Taiwan
D_{18}	*Hylocereus* sp.	magenta	Taiwan
D_{22}	*Hylocereus* sp.	magenta	Taiwan
Chaozhou large	*Hylocereus* sp.	magenta	Taiwan
Chaozhou 5	*Hylocereus* sp.	magenta	Taiwan
Small Nick	*Hylocereus* sp.	magenta	Taiwan
F_4	*Hylocereus* sp.	magenta	Taiwan
F_{11}	*Hylocereus* sp.	magenta	Taiwan
F_{13}	*Hylocereus* sp.	magenta	Taiwan
F_{17}	*Hylocereus* sp.	magenta	Taiwan
F_{18}	*Hylocereus* sp.	magenta	Taiwan
F_{22}	*Hylocereus* sp.	magenta	Taiwan

2.2 Parameters and Methods

2.2.1 Flowering phenology

- Period of the flowering season: The date of the first flower(s) opening to the date of the last flower(s) opening was recorded.
- A number of flowers and flowering cycles (flushes, waves)/year/plant: Flowers were considered as the same flowering cycle when they open at the same time (within 1 - 2 days) in a plant.
- Floral and fruit stages: Three to five randomly selected emerging floral buds were labelled and their development was recorded to identify the time taken for different floral and fruit stages.

2.2.2 Mating systems

- Hand self-pollination and hand cross-pollination were applied to identify the matting systems: self-compatible (SC) or self-incompatible (SI). For hand cross-pollination, the anthers of mature flower buds were removed and the flowers were bagged before 14.00 pm. These flowers in each genotype were hand-pollinated with a mixture of fresh pollen collected 5 - 20 minutes previously from 3 - 4 other genotypes at the early morning of the next day (5.00 - 6.00 am) and re-bagged. For hand self-pollination, mature flower buds were covered by bags before 14.00 pm, and pollen from the same flower applied to the stigma at the early morning of the next day (5.00 – 6.00 am). To prevent open pollination, the flowers were bagged except during pollination.
- Fruit set rate (%) was calculated by (the number of fruits/ the number of flowers) × 100. The degrees of sexual compatibility were assigned into 4 types:

- \+ Full self-compatible (F-SC): 70 - 100% fruit set after hand self- pollination.
- \+ Partial self-compatible (P-SC): 40 - 70% fruit set after hand self- pollination.
- \+ Partial self-incompatible (P-SI): 10 - 40% fruit set after hand self- pollination.
- \+ Complete self-incompatible (C-SI): 0 - 10% fruit set after hand self- pollination.
- All fruits from hand pollination were harvested and weighted using an electronic balance.

2.3 Statistical Analysis

All parameter values were represented by the arithmetic means using Excel software 2010. Fruit weights between hand self-pollination and hand cross-pollination were measured and compared by using Duncan's multiple range tests at a significance level of $p \leq 0.05$.

3. RESULTS AND DISCUSSION

3.1 Flowering Phenology of the Pitaya Collection of Genotypes

Flowering season period, number of flowering cycles and flowers/plant/season, floral and fruiting stages of 30 pitaya genotypes under the summer season 2014 in Pingtung, Taiwan are summarised in Table 2. The natural flowering season occurs from the beginning of June to the end of October. The red or magenta pulp genotypes flowered earlier but ended inflorescence latter than white flesh pulp genotypes. A wide range of flowering cycles and flowers/plant/season were found among genotypes, which produced 3 – 6 flowering flushes with 9 – 40 flowers. The floral and fruit stages spent 14 – 18 days and 27 – 33 days,

Table 2. Flowering season, number of flowering cycles and flowers/plant/season, floral and fruiting stages of 30 pitaya genotypes in Pingtung, Taiwan

Genotype	Flowering season period	Flowering cycles/season (cycles)	Flowers/ plant/season (flower)	Floral duration (day)	Fruiting duration (day)
VN-White	25/6 – 26/9	5	31	15	30
Chuchi Luu	15/7 – 19/9	3	14	16	29
P Long	16/7 – 22/9	3	9	16	30
Pink	3/7 – 30/10	6	32	15	29
WE 23	21/6 – 10/10	5	34	14	29
Orejona	9/6 – 23/9	4	15	18	32
Criollo	9/6 – 25/9	3	11	18	33
Malagu	7/6 – 5/10	4	13	18	33
Cebra	9/6 – 23/9	4	10	18	32
Lisa	8/6 –15/9	3	10	18	33
Rosa	9/6 – 15/10	5	23	18	33
Damao 9	9/6 – 15/9	4	16	17	31
Jhubei 1	10/6 – 04/10	5	15	15	29
Jhubei 3	12/6 – 20/9	5	28	15	30
D_2	10/6 – 20/10	6	24	14	28
D_4	9/6 – 1/10	4	19	15	27
D_{11}	8/6 – 25/10	6	30	15	29
D_{13}	9/6 – 25/10	6	38	14	27
D_{15}	19/6 – 28/10	5	30	13	27
D_{18}	19/6 – 28/10	6	40	14	27
D_{22}	8/6 – 28/10	6	30	14	27
Chaozhou large	8/6 – 28/10	6	32	16	28
Chaozhou 5	9/6 – 28/10	5	36	17	28
Small Nick	9/6 – 20/8	4	15	14	27
F_4	9/6 – 18/9	6	29	14	27
F_{11}	8/6 – 30/10	6	35	16	29
F_{13}	4/7 – 1/10	5	31	14	27
F_{17}	4/7 – 30/10	5	20	14	27
F_{18}	9/6 – 30/10	6	30	14	27
F_{22}	9/6 – 30/10	6	35	14	27

respectively. Among the collected genotypes, 6 genotypes were from America and had a longer time of floral and fruit stages.

It is obvious that the pitaya genotypes in this study belong to the long-day plants and they naturally produced flowers from summer to autumn, which is similar to those cultivated in Israel [8,10], Mexico [16] and Sri Lanka [9]. However, it is can be seen that flowering season in summer 2014 started one month later than that in summer 2013 [27]. This is becausethe temperatures of the period from November 2013 – February 2014 were lower than that of the same period of previous year (data not shown). Some studies [28,5,29] concluded that neither day length nor temperature alone could induce evocation and formation of flower buds in different pitaya species. For example, pitaya plants are 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 [6].

According to Jiang et al. [28], shoots flushed before December are classified as noncurrent and those flushed after December are classified as current. Floral buds have been reported to emerge simultaneously in April in Taiwan from current and noncurrent shoots of red pitaya [23]. The study indicated that the lower temperatures in the winter and spring of this study gave longer times for sprout and growth of new shoots as well as flower differentiation on both current and noncurrent shoots. Notably,

Table 3. Mating systems and fruit set, fruit weight resulted by involved pollination types of 30 pitaya genotypes

Genotype	Hand self-pollination		Hand cross-pollination		Matting system
	Fruit set (%)	Fruit weight (g/fruit)	Fruit set (%)	Fruit weight (g/fruit)	
VN-White	100.0	425.4^{a*}	93.8	390.7^{b}	F-SC
Chuchi Luu	100.0	360.7^{b}	100.0	399.0^{a}	F-SC
P Long	80.0	314.4^{b}	100.0	355.2^{a}	F-SC
Pink	0.0	–	75.0	237.1	C-SI
WE 23	0.0	–	72.7	351.8	C-SI
Orejona	0.0	–	88.9	292.2	C-SI
Criollo	0.0	–	75.0	290.4	C-SI
Malagu	0.0	–	100.0	277.2	C-SI
Cebra	0.0	–	83.3	327.6	C-SI
Lisa	0.0	–	100.0	456.6	C-SI
Rosa	0.0	–	78.6	447.6	C-SI
Damao 9	0.0	–	100.0	387.5	C-SI
Jhubei 1	0.0	–	88.9	392.3	C-SI
Jhubei 3	0.0	–	100.0	368.9	C-SI
D_2	0.0	–	100.0	359.8	C-SI
D_4	100.0	306.4^{b}	100.0	392.7^{a}	F-SC
D_{11}	0.0	–	93.3	421.3	C-SI
D_{13}	0.0	–	86.7	267.9	C-SI
D_{15}	0.0	–	72.7	396.8	C-SI
D_{18}	0.0	–	81.8	429.3	C-SI
D_{22}	0.0	–	100.0	443.4	C-SI
Chaozhou large	73.3	259.2^{b}	100.0	475.3^{a}	F-SC
Chaozhou 5	61.1	253.4^{b}	100.0	408.9^{a}	P-SC
Small Nick	0.0	–	100.0	366.7	C-SI
F_4	85.7	302.2^{b}	100.0	377.6^{a}	F-SC
F_{11}	0.0	–	93.3	418.3	C-SI
F_{13}	0.0	–	91.7	307.7	C-SI
F_{17}	50.0	132.5^{b}	85.7	381.7^{a}	P-SC
F_{18}	0.0	–	100.0	371.5	C-SI
F_{22}	0.0	–	76.5	381.8	C-SI

–, no data due to no fruit set.

** Mean fruit weight of each genotype (in each line) followed by the same letter is not significantly different at P≤ 0.05 according to Duncan's multiple range test.*

genotypes which charactrises a large number of flowers and wide flowering season are valuable materials for improving fruit yield and fruit production extension.

Different genotypes require various critical day-length and temperature accumulations for flower initiation. Almost all the red or magenta flesh genotypes exhibited more expanded flowering season than white flesh pulp genotypes. They started flowering sooner (the beginning of June) but finished that later (the end of October). The results and analyses above may lead to the postulation that red flesh species require lower temperatures and shorter day length for flower initiation than white-fleshed species. This postulation is consistent with the previous studies done in Taiwan [24,22] and in Israel [8].

3.2 Mating Systems of the Pitaya Genotypes

Based on the results of fruit set and fruit weight after hand self- and cross-pollination, the breeding system of each pitaya genotype is indicated in Table 3. Among 30 genotypes tested, 6 genotypes (VN-White, Chuchi Luu, P Long, D_4, Chaozhou large and F_4) were F-SC due to high FSPs of 73.3 – 100% after receiving their own pollen and 2 genotypes (Chaozhou 5 and F_{17}) were P-SC, getting 60.1 % and 50% fruit set, respectively after the same pollination method. In contrast, the others were not able to develop or set a very low fruit percentage after self-pollination, and thus they were C-SI. Hand cross-pollination gave high FSPs (72.7 – 100%) in all genotypes and larger fruits than hand self-pollination in most genotypes except for VN-White.

Some previous studies also demonstrated that different breeding systems and the various levels of self-compatibility emerged in different pitaya species of the same genus (*Hylocereus* sp.) [13,15,9,16,10] even in the same species (*H. undatus*) [12,10]. Weiss et al. [10] concluded that self-compatible or self-incompatible species had higher fruit set after being cross-pollinated with other. This finding was found true for most of the genotypes used except for VN-White, Chuchi Luu and D_4 with 100% fruit set after hand self-pollination. In addition, VN-White producing larger fruits following to hand self-pollination than hand cross-pollination indicated that the occurrence of a relatively strong SC mechanism in this genotypes. VN White is completely and strongly autogamous, possibly due to its long selection in Vietnam.

Studies of the mating system lead to some practical conclusions regarding the desired orchard design for some potential genotypes: 1) VN-White genotype can be planted alone because of the high fruit set obtained by self-pollination. 2) Fruit production in Chuchi Luu, D_4, Chaozhou large, Chaozhou 5 and F_4 would get more benefit from planting this species with pollenisers of other clones blooming synchronously.

4. CONCLUSION

The diversity and variability for flowering phenology and mating systems in the collection of pitaya genotypes give a strong suggestion that these accessions are valuable for germplasm application of this exotic fruit crop. Some genotypes that exhibited good reproductive characteristics such as wide flowering season, a high number of flowering flushes and flowers, strong self-fruiting and large fruits could be promising for further multiplication in commercial cultivation in southern Taiwan. If being used as a cultivar, some genotypes which have extended flowering season that requires less temperature and day-length for flower initiation should be chosen to induce off-season fruit production. In addition, it is necessary to comprehensively indicate pollination requirement for each genotype, which can help to design desired planting system orchards. The suitable pollination vector, self- or cross-pollination, should be also recommended to achieve the most effective fruit production.

ACKNOWLEDGEMENTS

Authors appreciate National Pingtung University of Science and Technology (NPUST), Department of Plant Industry, and Fruit crop Lab. for provision of funds and materials that were suitable to accomplish this work.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Mizrahi Y, Nerd A, Nobel PS. Cacti as a crop. Horticultural Review. 1997;18:291-320.
2. Mizrahi Y, Nerd A. Climbing and columnar cacti: New arid land fruit crops. In: Janick

J, editor. Perspective in new crops and new uses. 1st ed. Alexandria: American Society for Horticultural Science Press. 1999;358-366.

3. Mizrahi Y, Nerd A, Sitrit Y. New fruit for arid climates. In: Janick J, Whipkey A, editors. Trends in new crops and new uses. 1st ed. Alexandria: American Society for Horticultural Science Press. 2002;78-384.
4. Jiang YL, Liao YY, Lin TS, Lee CL, Yen CR, Yang WJ. The photoperiod-regulated bud formation of red pitaya (*Hylocereus* sp.) Hort Science. 2012;47: 1063-1067.
5. Khaimov A, Mizrahi Y. 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. 2006;81:465-470.
6. Khaimov A, Novák O, Strnad M, Mizrahi Y. The role of endogenous cytokinins and environmental factors in flowering in the vine cactus *Hylocereus undatus.* Israel Journal of Plant Sciences. 2012;60:371-383.
7. Le Bellec F, Vaillant F, Imbert E. Pitahaya (*Hylocereus* spp.): A new fruit crop, a market with a future. Fruits. 2006;61:237-250.
8. Nerd A, Sitrit Y, Kaushik RA, Mizrahi Y. High summer temperatures inhibit flowering in vine pitaya crops (*Hylocereus* spp.). Scientia Horticulturae. 2002;96:343-350.
9. Pushpakumara DKNG, Gunasena HPM, Karyawasam M. Flowering and fruiting phenology pollination vectors and breeding systems of dragon fruit (*Hylocereus* Spp.). Sri Lankan Jounal of Agricultural Science. 2005;42:81-91.
10. Weiss J, Nerd A, Mizrahi Y. Flowering behavior and pollination requirements in climbing cacti with fruit crop potential. Hort Science. 1994;29:1487-1492.
11. Yen CR, Chang FR. Forcing pitaya (*Hylocereus undatus* Britt. & Rose) by chemicals and controlled daylength and temperature. In: Proceeding of the symposium on enhancing competitiveness of fruit industry. Taichung District Agricultural Improvement Staion, Taiwan. 1997;163–170.
12. Castillo R, Livera M, Márquez GJ. Morphological characterization and sexual compatibility of five pitahayas (*Hylocereus undatus*) genotypes. Agrociencia. 2005; 39:183-194.
13. Lichtenzveig J, Abbo S, Nerd A, Tel-Zur N, Mizhrahi Y. Cytology and mating systems in the climbing cacti *Hylocereus* and *Selenicereus*. American Journal of Botany. 2000;87:1058-1065.
14. Merten S. A review of *Hylocereus* production in the United States. Journal of the Professional Association for Cactus Development. 2003;5:98-105.
15. Ortiz YDH, Livera MM, Carrillo SJA, Valencia BAJ, Castillo MR. Agronomical, physiological, and cultural contributions of pitahaya (*Hylocereus* spp.) in Mexico. Israel Journal of Plant Sciences. 2014;60: 359-370.
16. Valiente-Banuet A, Santos Gally R, Arizmendi MC, Casas A. Pollination biology of the hemiepiphytic cactus *Hylocereus undatus* in the Tehuacán Valley, Mexico. Journal of Arid Environments. 2007;68:1-8.
17. Cohen H, Tel-Zur N. Morphological changes and self-incompatibility break down associated with autopolyploidization in *Hylocereus* species (Cactaceae). Euphytica. 2012;184:345-354.
18. Tel-Zur N, Dudai M, Raveh E, Mizrahi Y. Selection of interspecific vine cacti hybrids (*Hylocereus* spp.) for self-compatibility. Plant Breeding. 2012;131:681-685.
19. Hang NTN, Hoa NV, Chau NM, Chang WN. Research strategies to increase sustainable production of dragon fruit and passion fruit. In: Proceedings of the workshop on increasing production and market access for tropical fruit in southeast Asia. Southern Horticultural Research Institute (SOFRI), Vietnam. Published by SOFRI, Vietnam. 2014;115-119.
20. Tel-Zur N, Abbo S, Bar-Zvi D, Mizrahi Y. Genotype identification and genetic relationship among vine cacti from the genera *Hylocereus* and *Selenicereus* based on RAPD analysis. Scientia Horticulturae. 2004;100:279-289.
21. Tel-Zur N, Abbo S, Mizrahi Y. Cytogenetics of semi fertile triploid and aneuploid intergeneric vine cacti hybrids. Journal of Heredity. 2005;96:124-131.
22. Yen CR. Improveing production and quality of selected tropical fruit through breeding and management. In: Proceedings of the workshop on increasing production and market access for tropical fruit in southeast

Asia. SOFRI, Vietnam. Published by SOFRI, Vietnam. 2014;59-68.

23. Hsu WT. Investigations on culture, growth habits and phenology in pitaya (*Hylocereus* spp.). Master Thesis, National Taiwan University, Taiwan; 2004.
24. Su YH. Effects of photoperiod and pruning on off-season production in piataya (*Hylocereus* spp). Master Thesis, National Pingtung University of Science and Technology, Taiwan; 2005.
25. Zee F, Yen CR, Nishina M. Pitaya dragon fruit, strawberry pear. Fruits and Nuts. 2004;9:1-3.
26. Hoa TT, Clark CJ, Waddell BC, Woolf AD. Postharvest quality of dragon fruit (*Hylocereus undatus*) following disinfesting hot air treatments. Postharvest Biology and Technology. 2006;41:62-69.
27. Tran DH, Yen CR. Morphological characteristics and pollination requirement in red pitaya (*Hylocereus* spp.). International Journal of Agricultural, Biosystems Science and Engineering. 2014;8:6-10.
28. Jiang YL, Lin TS, Lee CL. Phenology, canopy composition and fruit quality of yellow pitaya in tropical Taiwan. Hort Science. 2011;46:1497-1502.
29. Nerd A, Tel-Zur N, Mizrahi Y. Fruits of vine and columnar cacti. In: Nobel PS, editor. Cacti biology and uses. 1st ed. Berkeley: University of California Press. 2002;185-198.

Peer-review history:
The peer review history for this paper can be accessed here:
http://prh.sdiarticle3.com/review-history/26161