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Planting Density of Red Pitaya (*Hylocereus Polyrhizus*) to Achieve Optimum Yield Under Malaysia Weather Condition

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Abstract **– Red Pitaya (*Hylocereus polyrhizus*) was commercially been planted in Malaysia in the early 2000's. It grows well under local weather condition and started to fruit within a year after planting. Red pitaya received high demand from domestic market due to its high nutrition value. A study was conducted to improve the yield productivity of red pitaya planting by introduced two intensive planting densities at 1,815 trellis plants/ha (3.0m x 1.8m) and 1, 556 trellis plants/ha (3.0m x 2.1m) as compared with the common planting density at 1,361 trellis plants/ha (3.0m x 2.4m). This study was laid out in Randomised Complete Block Design in three replications with 30 recorded trellises per density. This study was conducted for four years. The cumulative yield over four years of harvesting showed that the highest planting density at 1,815 trellis plants/ha produced 48.7 t/ha (170, 066 fruits/ha), followed by 41.8 t/ha (152, 177 fruits/ha) and 38.2 t/ha (133, 786 fruits/ha) with the planting density of 1, 556 trellis plants/ha and 1, 361 trellis plants/ha, respectively. The average fruit weight and fruit number per trellis among the planting densities were almost similar and ranged from 276-293 g/fruit and 94-98 fruits per trellis, respectively. The high planting density at 1, 815 trellis plants/ha did not affect the fruit number and fruit weight, but increased the total fruit yield of red pitaya by 26.5%. Therefore, the high planting densities at 1,815 trellis plants/ha was recommended for red pitaya planting under Malaysia weather condition to achieve the optimum yield productivity.**

Keywords **– Average Fruit Production; Average Fruit Weight; Long Day Plant; Total Fruit Yield; Yield Improvement.**

I. Introduction

Red Pitaya (*Hylocereus polyrhizus*) or locally known as dragon fruit in Malaysia was introduced for commercial planting in the early 2000's. Red pitaya is a night-blooming vine cacti that belong to the cactus family (Cactaceae) [1] and this species was reported to be indigenous from the tropical rainforest of Nicaragua, Costa Rica and Panama [2]. Dragon fruit can with stand prolonged drought, therefore this fruit species also suitable for grown in the area where drought is a limiting factor for fruit production [3]. Red pitaya is the most popular and acceptable pitaya species by domestic market due to its excellent taste, attractive red-violet flesh colour and high nutrition value. Betacyanins is the important fruit pigments of red pitaya fruits which contributed for the red colour [4]. The betacyanins content is higher in red pitaya fruit flesh as compared to the peel [5]. Betacyanins also has a strong antioxidant capacity, which is very useful as natural pigment to provide defence against oxidative stress [6], [7]. Red pitaya also contains high amounts of flavonoids and phenolic acids from both flesh and peels, where these properties have healthy benefits for human diet and could be exploited for the formulation of nutraceuticals and food applications [8]. Pitaya seeds were contained high amount of essential fatty acids such as linoleic and linolenic could be used as a new source of essential oil [9], [10].

Currently, the total cultivated area of red pitaya fruit in Malaysia was increased from 502 ha in year 2005 to 1, 641 ha in 2013. The total fruit production of red pitaya was recorded 10, 961 tonnes with the wholesale value of RM 55.51 million [11]. Red pitaya is a fast growing crop under Malaysian weather condition and fruiting within a year after planting. In Malaysia, red pitaya was mainly been planted by small holders. The information of agronomic practices on red pitaya planting is still unavailable for the growers to improve their fruit yield and productivity. The planting of red pitaya was mainly depends on the vertical structure support, where the concrete or wooden pillar are normally been used as the trellis in red pitaya planting. The planting distances of these trellises are basically recommended between 2.0m to 3.0m among the trellises [12]. In Malaysia, the planting distance of 3.0m x 2.4m in rectangular formation with 1, 361 trellis plants/ha is the most common planting density of red pitaya cultivation. Based on observation, the branches canopy size of red pitaya are smaller than 2.0m in diameter. This common planting distance at 3.0m x 2.4m can be further reduced to increase the planting density to improve the land productivity and higher fruit yield.

Therefore, an experiment was conducted on high density planting of red pitaya at 1,815 trellis plants/ha (3.0m x 1.8m) and 1,556 trellis plants/ha (3.0m x 2.1m) as compared with the common planting density at 1,361 trellis plants/ha (3.0m x 2.4m) to study the effect on average fruit weight, total fruit production and fruit yield improvement of red pitaya planting under Malaysia weather condition.

II. Materials and Method

A. Study Site

This study was carried out in Felda Agricultural Services Sdn. Bhd. Sg. Tengi Research Station, Selangor, Malaysia, about 45 km toward the north of the capital city of Kuala Lumpur. The site was located on 3°32' latitudes North and 101°27' longitudes East and the altitude is 32m above sea level. The average annual rainfall of the study area during the study period was 2,320 mm. The soil type is organic clay texture. The chemical properties of the soil at the depth of 0-15 cm are pH - 4.7, organic carbon – 2.02%, cation exchange capacity – 6.77 cmol (+)/Kg, total nitrogen – 0.07%, available phosphorus – 64 mg/Kg, exchangeable potassium – 0.36 cmol (+)/Kg, exchangeable calcium – 1.76 cmol (+)/Kg and exchangeable magnesium – 0.68 cmol (+)/Kg.

B. Experimental Design

The experiment was laid out in Randomised Complete Block Design (RCBD) with three replications. The red pitaya was planted by three planting densities at 1,815 trellis plants/ha (3.0m x 1.8m), 1,556 trellis plants/ha (3.0m x 2.1m) and 1361 trellis plants/ha (3.0m x 2.4m) in rectangular formation in nine experiment plots. The size of each plot is estimated at 0.2 ha. One planting rows in the centre of each experiment plot that consisted of 10 trellis plants were selected for data recording. A total of 30 trellis plants were recorded to represent each planting density. The mixture fertilizer (nutrients ratio of 9.6/4.8/17.6/2.4) at 1.2 kg/trellis plant/year and compost at 2 kg/trellis plant/year was applied equally in each planting density.

C. Data Collection

Table 1. Total fruits produced of red pitaya in various planting densities.

Planting Distances	Densities (trellis plants/ha)	Average Fruit Production (numbers/trellis plant)					Total Fruit Production (numbers/ ha)
		Year 1	Year 2	Year 3	Year 4	Cumulative (Year 1-4)	Cumulative (Year 1-4)
3.0m x 1.8m	1,815	7.9 a	10.8 a	44.9 a	30.1 a	93.7 a	170,066 a
3.0m x 2.1m	1,556	7.7 a	10.8 a	45.5 a	33.8 a	97.8 a	152,177 b
3.0m x 2.4m	1,361	5.8 a	11.9 a	47.7 a	32.9 a	98.3 a	133,786 c

Mean with the same letter are not significantly different according to DMRT at 5%.

The data recording was included the total fruit produced per trellis plant, average fruit weight, total fruit yield per trellis plant and total fruit yield per ha. The red pitaya was started to harvest almost a year after planting. The harvested red pitaya fruits were composited from each planting rows (10 trellis plants) in each experiment plot to determine the average fruit production per trellis plant, average fruit weight, average fruit yield per trellis plant and fruit yield per ha. The fruit was harvested according to each fruiting batch and composited as yearly data for all the recorded parameters.

D. Data Analysis

Table 2. Average fruit weight of red pitaya in various planting densities

Planting Distances	Densities (trellis plants/ha)	Average Fruit Weight (g/fruit)			
		Year 1	Year 2	Year 3	Year 4
3.0m x 1.8m	1,815	283.6 a	303.4 a	329.5 a	214.1 a
3.0m x 2.1m	1,556	289.5 a	297.1 a	311.2 a	219.1 a
3.0m x 2.4m	1,361	336.5 a	317.8 a	308.6 a	234.0 a

Mean with the same letter are not significantly different according to DMRT at 5%.

All the data were analyzed with analysis of Variance (ANOVA) to determine the differences between different planting densities and separation with Duncan's Multiple Range Test (DMRT) at 5% probability level by using Statistical Analysis System programme (SAS).

III. Results

A. Total Fruit Production

The fruit production of red pitaya was monitored to determine the effect of high density planting on the average fruit production of each individual trellis. The yearly fruit production over the four years of study showed no significant different on the average fruit numbers been produced per trellis plant among the different planting densities. The average fruit production per trellis plant ranged from 5.8 - 7.9 fruits/trellis plant, 10.8 - 11.9 fruits/trellis plant, 44.9 - 47.7 fruits/trellis plant and 30.1-33.8 fruits/trellis plant respectively at 1st, 2nd, 3rd and 4th year of harvesting (Table 1). The cumulative total fruits produced per trellis plant over the four years of harvesting also showed no significant different at 93.7 fruits/trellis plant, 97.8 fruits/trellis plant and 98.3 fruits/trellis plant respectively for the planting density of 1,815 trellis plants/ha, 1,556 trellis plants/ha and 1,361 trellis plants/ha (Table 1). However, the high planting density are able to produce higher total fruit numbers per ha over the four years of harvesting. The total fruit production per ha was significantly increased from 133,786 fruits/ha at the common planting density (1,361 trellis plants/ha) to 152,177 fruits/ha and 170,066 fruits/ha in the higher planting density of 1,556 trellis plants/ha and 1,815 trellis plants/ha, respectively (Table 1). It was clearly showed that the highest planting density at 1,815 trellis plants/ha and 1,556 trellis plants/ha were able to produce higher total fruit per ha.

Meanwhile, the average fruit weight of red pitaya was showed no significant different among the fruits that produced from different planting densities. The average fruit weight was ranged from 283.6 - 336.5 g/fruit, 297.1 - 317.8 g/fruit, 308.6 - 329.5 g/fruit and 214.1 - 234.0 g/fruit, respectively at 1st, 2nd, 3rd and 4th year of harvest (Table 2). The average fruit weight of red pitaya in this study was comparable with other studies that had reported the fruit weight ranged from 300 - 393 g/fruit [13], [14]. This result was showed that the higher planting density until 1,815 trellis plants/ha was not affected the average fruit weight of red pitaya. The growth of red pitaya fruit normally exhibited a sigmoid pattern, where the growth of fruit length, diameter and weight was rapid during 25 days after flower anthesis [15]. The increase of plant growth hormone, such as Gibberellic acid in red pitaya fruit content [16], cross-pollination of red pitaya with other *Hylocereus* spp. [17] and the total numbers of viable seeds in the red pitaya fruit [18] were the major factors that improved the fruit weight of red pitaya.

B. Yield Improvement

The yearly record on the average fruit yield per trellis plant during the four years of study were no significant different among the different planting densities. The average fruit yield per trellis plant was ranged from 1.97 - 2.23 kg/trellis plant, 3.24 - 3.80 kg/trellis plant, 14.14 - 14.92 kg/trellis plant and 6.44 - 7.69 kg/trellis plant at 1st, 2nd, 3rd and 4th year of harvesting (Table 4). The cumulative average fruit yield per trellis plant over the four years of harvesting at the higher planting density of 1,815 trellis plants/ha and 1,556 trellis plants/ha were recorded 26.74 kg/trellis plant and 26.93 kg/trellis plant, respectively were showed no significant different as compared to the common planting density (1,361 trellis plants/ha) that had recorded 28.18 kg/trellis plant (Table 3). The cumulative average fruit yield per trellis plant was similar among the different planting densities had been contributed by the similar fruit numbers and fruit weight been produced per trellis plant, which are not affected by the closer planting in higher density planting in this study.

However, the total yield per ha of red pitaya was significantly improved by high density planting at 1,815 trellis plants/ha as compared to the common planting at 1,361 trellis plants/ha. Where, the total yield was significantly improved from 2.68 t/ha to 4.06 t/ha, 5.18 t/ha to 5.90 t/ha and 20.04 t/ha to 26.90 t/ha, respectively at 1st, 2nd and 3rd year of harvesting, except at the 4th year of harvesting (Table 4). Unfortunately, the planting density at 1,556 trellis plants/ha was unable to improve the total yield as compared to the common planting density at 1,361 trellis plants/ha during the four years of study (Table 4). The cumulative yield per ha over the four years of harvesting on the high density planting at 1,815 trellis plants/ha was successfully to improve the fruit yield of red pitaya significantly by 26.5% to achieved 48.53 t/ha as compared to the common planting density (1,361 trellis plants/ha) which only recorded at 38.36 t/ha (Table 4).

Table 3. Yield per trellis plant of red pitaya with various planting densities

Planting Distances	Densities (trellis plants/ha)	Average Fruit Yield (kg/trellis plant)				
		Year 1	Year 2	Year 3	Year 4	Average (Year 1-4)
3.0m x 1.8m	1,815	2.23 a	3.25 a	14.82 a	6.44 a	26.74 a
3.0m x 2.1m	1,556	2.22 a	3.24 a	14.12 a	7.36 a	26.93 a
3.0m x 2.4m	1,361	1.97 a	3.80 a	14.73 a	7.69 a	28.18 a

Mean with the same letter are not significantly different according to DMRT at 5%.

Table 4. Total yield per hectare of red pitaya in various planting densities

Planting Distances	Densities (trellis plants/ha)	Total Yield (t/ha)				
		Year 1	Year 2	Year 3	Year 4	Average (Year 1-4)
3.0m x 1.8m	1,815	4.06 a	5.90 a	26.90 a	11.69 a	48.53 a (126.5%)
3.0m x 2.1m	1,556	3.45 ab	5.04 b	21.97 b	11.45 a	41.91 b (109.2%)
3.0m x 2.4m	1,361	2.68 b	5.18 b	20.04 b	10.47 a	38.36 b (100%)

Mean with the same letter are not significantly different according to DMRT at 5%.
(   ) - % over the planting density of 1,361 trellis plants/ha

IV. Discussions

Red pitaya is a long day plant [19] which requires longer sunshine for induce flowering and fruiting. The longer sunshine hour during the dry season was found to be the major factor that triggered the flowering of red pitaya under Malaysian weather condition [20]. The moderate temperature during dry season about 32°C is another major factor that able to induce heavy flowering of red pitaya as compared to extreme high and low temperature [21]. The climbing cacti such as *Hylocereus* sp. was originated in shady habitats of subtropical and tropical climate, however red pitaya are light tolerant under exposed condition due to their unique skin characteristic with layer of wax cover and thick skin [21].

Fig. 1. Branches canopy of red pitaya at the planting distance of 3.0m x 1.8m (left), 3.0m x 2.1m (centre) and 3.0m x 2.4m (right) at 4th year after harvesting.

Even though, the high density planting of red pitaya at 1,815 trellis plants/ha may cause some over-crowded canopy and shading effect from the dense branches among the trellis plants, which may affect the total fruit production and yield per ha. However, the results in this study were clearly demonstrated that the high density planting of red pitaya at 1,815 trellis plants/ha was not affected the total fruit produced per trellis, average fruit weight and average fruit yield per trellis plant as compared to the common planting density at 1,361 trellis plants/ha. This is due to the trellis plant distance of 2.4m under the planting density at 3.0m x 2.4m (1,361 trellis plants/ha) was still far among the trellis plants, where about 0.6m of the space between the red pitaya branches as illustrated in Fig. 1. Higher planting densities at 1.5 - 2.5m x 1.0 - 2.5m had been demonstrated in other trial, where the result was proven that the yield of red pitaya planting was able to achieved 28 - 34 t/ha in the 4th and 5th year of harvesting [15]. Besides, the cross pollination of red pitaya among the different red pitaya flowers and white pitaya (*Hylocereus undatus*) flowers were very important to ensure the 100% fruit set of the red pitaya flowers and increased the fruit weight and the total yield production as compared to those red pitaya flowers that self-pollinated [18]. Therefore, higher planting density is able to improve the yield productivity of red pitaya planting to achieve up to 26.90 t/ha as compared to common planting density in Malaysia.

V. Conclusion

The high density planting of red pitaya at 1,815 trellis plants/ha (3.0m x 1.8m) was able to improve the cumulative fruit numbers per ha and the cumulative fruit yield per ha over the four years of study by 27.1% and 26.5% respectively as compared to the common planting density at 1,361 trellis plants/ha. Therefore, higher planting density at 1,815 trellis plants/ha (3.0m x 1.8m) is the most preferable planting density for red pitaya under Malaysian weather condition to maximize the total fruit yield per ha. However, some pruning is needed to avoid the overlapping of branches between the trellises which may cause inconvenient during harvesting.

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