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Science and Technology

Meri-Rastilantie 3 B, FI-00980
Helsinki, Finland
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Journal of Food, Agriculture & Environment Vol.6(3&4) : 305-311. 2008

www.world-food.net

Growth, yield and fruit quality of red dragon (*Hylocereus polyrhizus*) fruit as affected by plant support system and intercropping with long bean (*Vigna sinensis*)

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Received 17 March 2008, accepted 21 September 2008.

Abstract

Climbing epiphytic cacti, particularly members of the genera *Hylocereus* known as pitaya or dragon fruit, have recently drawn much attention of growers worldwide because of their economic value as food products and also owing to their high nutritive and medicinal values. These cacti are branched climbers needing strong structures to ensure their vigorous growth and heavy fruit yield for maximum yield production. Various designs of structure have been used to provide such support. In addition, it normally takes 8 to 12 months for dragon fruit to bear fruits after planting. Thus, it would be useful to practice intercropping during this juvenile period of dragon fruit. Therefore, a study was conducted to determine the effects of using three different plant support systems: the pole, T bar trellis and V shape, on growth, yield and fruit quality of dragon fruit and to evaluate the use of long bean as an intercrop with dragon fruit. Red dragon fruit as the main crop and long bean as the intercrop were used in this study. Dragon fruit plants grown using the pole system showed 17–38% more flower buds, 15–36% more fruits and 24% heavier total fruit weight compared to those of the T bar trellis and V shape systems, respectively. There were also significant effects of plant support systems on soluble solid concentration (% Brix) where T bar trellis and pole systems showed 7% higher soluble solid concentration than that of the V shape system. Intercropping had no influence on all the parameters measured. Support systems did not have any significant effect on the stem diameter, chlorophyll concentration of stem, and days to attain fruit maturity in red dragon fruit and in the yield of long bean. Similarly, fruit quality including fruit pH, fruit diameter, fruit length, peel and pulp color and titratable acidity were not affected by different support systems or intercropping.

Key words: Dragon fruit, long bean, pole, T bar trellis, V shape, support system, intercropping, growth, yield, fruit quality.

Introduction

Dragon fruit or pitaya (*Hylocereus* sp.) is from the Cactaceae family. It originates from the drier tropical climate of Central America and is the most widely cultivated hemiepiphytic cactus in many developing countries of Asia. It has a potential for commercial cultivation not only as a fruit commodity but also as a vegetable or forage [19, 17]. Being a new fruit species recently introduced to the Malaysian agriculture, it is understood that dragon fruit has not been extensively studied under the local growing conditions. Most of the agronomic practices adopted by the local dragon fruit growers are mostly adapted from countries having longer experience in dragon fruit husbandry. Being a climbing cactus, dragon fruit needs a supporting structure to support its numerous branches and attach its roots. Using support structure also facilitates in agronomic management such as weeding, fertilizing, pruning and harvesting. Strong support is needed to support its heavy burden of branches. Cost of the construction of the support structure is approximately 32% of the total initial cost of dragon fruit cultivation. Hence, one aspect worth researching into is a more suitable and cost effective plant support system to bear the overhanging branches and allow for a more optimized land use.

A support system is important in order to bear the heavy burden of a climbing crop. A good support system would encourage the plant to grow well, encourage higher yield, produce quality fruit and allow for an easier management, thereby enhancing total yield potential. Extensive studies of plant support systems have been reported in other crops such as kiwi, peach, grape, cucumber, tomato, mucuna bean, winged bean, lima bean, sweet cherry and red raspberry. For example, in peach cultivation, a Y-shape system was shown to give higher yield compared to a central leader system[4]. Other than that, Shetty and Wehner [23] reported that vine length, incidence of powdery mildew, fruit shape, fruit quality, fruit firmness, marketable yield and percentage of culled fruits were all higher when cultivars of cucumber (*Cucumis sativus* L.) were grown on trellis support compared to flat-bed production systems. However, a cursory survey of the scientific literature revealed no report published on support system of dragon fruit. Currently, many local growers use reinforced concrete posts as vertical support with metal aerial support covered with plastic tube or concrete posts with wooden square frame at the top as horizontal support for the overhanging fruit bearing shoots.

Alternative planting support systems such as pergola and trellis should also be evaluated along side the currently popular concrete pole plant support system. Other aspect that needs information is the benefit of intercropping because the fruit bearing stage of a dragon fruit plant only begins at around 8 to 12 months after planting. It would be beneficial to introduce intercropping with cash crops such as vegetables and other short-term crops that can use the same support structure, so as to provide an early income to growers. Therefore, a study was conducted aiming at addressing the two aspects mentioned earlier: the plant support systems and intercropping. The objectives of the study were: 1) to compare three methods of plant support system on plant growth, yield and quality of dragon fruit and 2) to evaluate the effects of intercropping with long bean on growth, fruit yield and quality of dragon fruit.

(A) Pole system.

(B) V shape system.

(C) T bar trellis.

Plate 1. Three plant support systems.

Materials and Methods

The study was conducted in an area of 40 m x 15 m at the Universiti Agriculture Park, Universiti Putra Malaysia, Serdang, Selangor, Malaysia, over a planting period of 14 months from June 2004 to August 2005. The total recorded rainfall during the planting period was 2748.5 mm and the total annual rainfall for 2004 and 2005 were 2750.6 mm and 2175.7 mm, respectively. The experimental plot was on Serdang Series (Typic Kandiudults).

Dragon fruit plants of the single clone red variety (*Hylocereus polyrhizus*) were planted from cuttings taken from older stems of matured two-year old fruiting plants and were supplied by Nutri Red Plantation Sdn. Bhd., Kuala Pilah, Negeri Sembilan. Long bean seeds of MKP 5 variety were purchased from Malaysian Agricultural Research and Development Institute (MARDI), Jalan Kebun Station, Selangor. The study was conducted using a Randomized Complete Block Design in a factorial experiment with two factors. The first factor was plant support system, comprising three plant support systems (Plate 1): (A) Pole (B) V shape and (C) T bar trellis. The second factor evaluated was intercropping comprising (1) intercropping with long bean; and (2) without intercropping. Therefore, there was a total of 6 treatment combinations in each block with each treatment combination replicated 4 times, giving a total of 24 plots with each plot size measuring 5 m x 5 m.

The pole system had 3 concrete poles with 2 plants per pole and the poles were planted at 2.0 m in a equidistant triangular pattern. There were six plants per plot. The concrete pole measured 10 cm length x 10 cm width x 1.6 m height and had a square concrete top frame structure measuring 0.6 m x 0.6 m. The concrete pole was buried to a depth of 0.6 m. Two plants of long bean were planted for each pole system and there was a total of six plants per plot. The V shape system consisted of two main concrete poles (similar to the pole system) with 6 plants on three diagonal wooden structures with 2 plants per structure spaced 1.0 m apart and joined at the top with a wooden bar 7.6 cm thick. The distance between 2 main concrete poles was 3.1 m. Long bean was also planted in the same quantity with dragon fruit plant. In T bar trellis system, three concrete poles of similar dimension to the two systems were used as the main vertical poles. Each concrete pole was planted with two plants, giving a total of six plants per plot. Long beans were planted two plants per pole. The total of long bean was the same with dragon fruit plant. A horizontal wooden frame comprising three parallel bars (5.1 cm width x 7.6 cm thick x 2.5 m length) was placed on top of the concrete poles. The frame was also supported by slanting wooden bars on the end poles. All support systems were established before planting of the dragon fruit, whilst long bean was planted 4 months after the planting of dragon fruit. Fertilizer was applied at different stages of growth of dragon fruit using different commercial fertilizers at different rates of application as shown in Table 1.

Measurements at vegetative stage of dragon fruit: The *diameter of the main stem* at 100 cm above the soil surface was measured with a digital caliper (CD-6"C, Mitutoyo) at 5 months of age after planting. At this stage the stem has attained its maximum diameter.

The *chlorophyll content of the stem* was determined using acetone extraction method [7]. Samples from three plants per plot were taken randomly at the middle portion of the stems using a cork borer from each treatment. For each sample, three discs (0.8 cm diameter) were punched and the plant tissues were placed in 20 ml of 80% (v/v) acetone in a scintillation bottle covered with aluminum foil to avoid direct sunlight. All samples were kept in darkness (fridge) until the samples changed to white colour (complete extraction) after about 5 days. Readings were taken using a spectrophotometer (Model 25, Beckman, USA) at two wavelengths, 664 nm and 647 nm, and these readings were close

Table 1. Types, rates and stages of application of fertilizer for dragon fruit.

Type of fertilizer	Rate of application	Stage of application
Organic fertilizer (Amino-Q®) (1.38% N : 3.02% P_2O_5 : 0.98% K_2O)	350 g/plant	Early planting (basal fertilizer)
Compound fertilizer (Bioam®) (8:8:8)	350 g/plant	Early planting until 6 months (once a month)
Compound fertilizer (Bioam®) (8:8:12)	350 g/plant	After 6 months (once a month)
Foliar fertilizer (TS No.1®) (8:8:8)	100 mL/12 L	5 weeks after planting until 6 months (once a week)
Foliar fertilizer (TS No. 2®) (15:10:33)	100 mL/12 L	6 months onwards (once a week)

to the absorption peaks of 80% acetone for chlorophyll a and b, respectively. Chlorophyll content was obtained using the following equations: Chlorophyll a (mg cm^{-2}) = 13.19A $_{664}$ - 2.57A $_{647}$; Chlorophyll b (mg cm^{-2}) = 22.10 A$_{647}$ – 5.26 A$_{664}$; Total of chlorophyll = Chlorophyll a + chlorophyll b; Actual content = (3.5 x total chlorophyll)/3.0 where * 3.5 – total chlorophyll extract in cuvette (ml), * 3.0 – leaf area of chlorophyll extract (cm^2).

Yield of long bean: Young long beans of marketable quality (achieving desired length and free of blemishes) were harvested every three days until the end of their reproductive stage.

Measurements at reproductive stage of dragon fruit: The *total number of flower buds* produced for each plot was counted. Only the bud which had appeared and reached a diameter of about 4 mm was counted as a flower bud. The observations of new flower buds were taken at weekly intervals.

The *percentage of flowers aborted* was calculated by dividing the number of aborted flowers to the total number of flowers initially formed. Observations were made for all plants in a plot.

Days to fruit maturity measurement was counted as the number of days taken to reach maturity starting from flower bud stage to matured fruit stage.

Fruit number was obtained by counting all fruits harvested at maturity stage from planting up to 14 months.

Total fruit weight: Fruit weight was measured using an electronic balance (BL 6100, Sartorius) and fruit weight was recorded as total fruit weight for each plot.

Average fruit weight was obtained from the total fruit weight divided by the number of fruits for each plot over the total experimental period from planting up to 14 months.

Determination of fruit quality of dragon fruit: The *diameter* of each harvested fruit was measured using a digital caliper (CD-6"C, Mitutoyo). The measurement recorded was the average of two readings taken at two axes of the midsection of the fruit. *Soluble solids* concentration was measured with a hand refractometer (Model N1, Atago). *Fruit length*, measured from the part attached to the petiole to the base of the fruit, was taken manually using a ruler after it was harvested. *Fruit pH* was measured using 10 g of crushed pulp sample, mixed with 40 mL of distilled water and filtered. The filtered pulp was used to determine pH value using a pH meter (Jenway, model 3305).

Peel and pulp color determination: Random samples of the pulp and skin were taken and their color characteristics were scanned using Hunter Lab Colorimeter Ultrascan, model SN 7877 (Hunter Associates Lab, Inc., Virgina). The values read were L*, a* and b*. The L* value indicated the lightness of colour with value ranging from 0 = black to 100 = white. Positive a* indicated a hue of red-purple; negative a* of bluish-green; positive b* of yellow and negative b* of blue. Values a* and b* were coordinates that indirectly reflected hue and chroma, thus a more appropriate measure of colour was obtained from the calculation of hue angle (h^0) and Chroma (C*). Chroma C* referred to vividness of colour as computed by the formula, $C^* = (a^{*2} + b^{*2})^{1/2}$ which represented the hypotenuse of a right triangle with values ranging from 0 = least intense to 60 = most intense. The value h^0, referred to as colour, was the angle of tangent^{-1} b*/a* where 0^0 = red purple, 90^0 = yellow, 180^0 = bluish-green and 270^0 = blue.

Titratable acidity: Ten g of pulp sample was crushed/blended with 40 ml distilled water and filtered. Five ml of the filtrate was taken and titrated with 0.1 N NaOH until the pH reached 8.1 as shown by a pH meter. The volume of titre of 0.1 N NaOH was recorded and the result was calculated using the equation below: Titratable acidity = [Volume of NaOH (ml) x 0.1 N]/ Weight of sample (10 g).

The fruit quality measurements were carried out for all harvested fruits for each treatment.

Statistical analysis: Data on the effects of plant support system and intercropping were analysed by analysis of variance (ANOVA) using SAS software [21]. Main effects of each factor were compared using LSD when the effects were significant. If interactions between factors were significant, the data were analyzed comparing intercropping effects within each plant support system. Comparison was made between support system and planting system (intercropping or without intercropping).

Results and Discussion

Vegetative stage of dragon fruit: There was no significant difference in stem diameter and chlorophyll concentration of dragon fruit plants supported by the pole, T bar trellis and V shape support systems, and with or without intercropping. Stem diameter of the plants ranged from 42.14 to 43.49 mm. The chlorophyll content of dragon fruit stems at early vegetative growth ranged from 12.55 to 13.24 mg cm^{-2}. Neither support nor planting systems had any significant effects on the chlorophyll content of dragon fruit stem.

The yield of long bean for the first round ranged from 3.23 to 4.64 kg/plot, and for the second round from 2.82 to 3.97 kg/plot. Total yield of long bean ranged from 7.03 to 8.22 kg/plot (Table 2). However, different support systems used were found not to affect the yield of long bean for harvests of both first and second growing cycles, and also the total yield for the two cycles. The values for the yield of long bean on a per hectare area basis extrapolated from the values obtained from the plot measuring on the 5 m x 5 m and the yields of long bean were 2.983, 2.810 and 3.289 tons for pole, T bar trellis and V shape systems, respectively (Table 2).

Reproductive stage of dragon fruit

Total number of flower buds produced: During the reproductive stage of dragon fruit, there was significant effect of support systems on total flower buds produced/plot (Fig. 1). In this experiment, average total flower buds produced was 69, 59 and 50 flower buds/plot for pole, T bar trellis and V shape systems, respectively. The pole system had significantly a higher number

Table 2. Mean for yield of long bean for three support systems.

Support system	Harvest 1 (kg/plot)*	Harvest 2 (kg/plot)*	Total yield (kg/plot)	Yield per ha (tonnes)
Pole	4.64±0.40	2.82±0.41	7.46	2.983
T bar trellis	3.23±0.78	3.80±1.04	7.03	2.810
V shape	4.25±0.64	3.97±0.62	8.22	3.289

Differences were not significant at P>0.05 *Mean±S.E of flower buds produced than the T bar trellis and V shape systems. This finding concurred with that of Robinson [20] who reported that Y trellis training system intercepted more light. This probably might be due to a greater exposure of the shoots to sunlight that encouraged greater floral production. The pole system in this study and Y trellis system reported by Robinson [20] were different in design but both allowed the better exposure of the plants to sunlight. Normally in a commercial planting, there could be almost 10 flower buds per stem, but many of these flower buds did not reach blooming or matured fruit stage and only about three flower buds perpetuated to bloom and maintained until matured fruits. There was significant interaction ($P<0.05$) between support systems and intercropping on total number of flower buds produced (Fig. 2). In both the pole and T bar trellis support systems, total numbers of flower buds were not significantly different between intercropped and non-intercropped plants. However, in the V shape system, the intercropped plants had a greater number of flower buds than the non-intercropped. This indicated that intercropping was beneficial to dragon fruits only in the V shape system. One reason for this could be the greater shading under V shape system that may have prolonged the decomposition of the long bean residues, thus giving a longer term mulching and nutrient release compared to the more exposed pole and T bar trellis.

Percent flowers aborted: Planting support system showed significant effects on percentage flowers aborted. Pole system had a significantly lower percentage of flowers aborted compared to a V shape system (Fig. 3). Percent of flower aborted was 21, 24 and 28 for pole, T bar trellis and V shape systems, respectively. However, intercropping with long bean did not significantly affect percentage of flowers aborted. Flower abortion was reported to be influenced by several factors such as climate, fertilizer management or carbohydrate stress.

Fruit number: The number of fruits per plot over a 6-month period ranged from 11 to 15 fruits/plot. The pole support system gave a significantly greater number of fruits compared to the V shape system. There was no difference between V shape and T bar trellis systems with 11 to 13 fruits/plot, respectively (Fig. 4). The number of fruits produced were equivalent to 4,400 and 6,000 fruits/ha. The design of the pole system having a square top allows the branches to spread easily and it was exposed more to the sunlight. Due to that, it would influence the fruit production with adequate exposure to sunlight to produce more fruits resulting in total flower buds produced. There were no significant effects of intercropping on fruit number.

It was observed that the pole support system contributed to the efficiency of the system in achieving a full productive potential for higher yield because of its suitable structure design. On the other hand, dragon fruit growth was observed to be restricted and the branches overlapped each other in the V shape support system because of its limited space to spread its branches. From this observation the pole and T bar trellis support systems were able to expose the fruits well above the height of the system, but the pole system was still the best system since it produced a higher number of fruits.

Total fruit weight: In tandem with fruit number, total fruit weight/

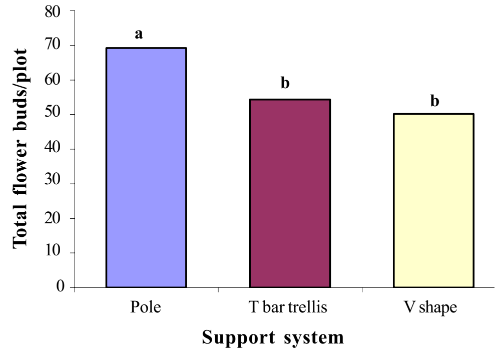

Figure 1. Effect of support systems on total flower buds produced/plot.

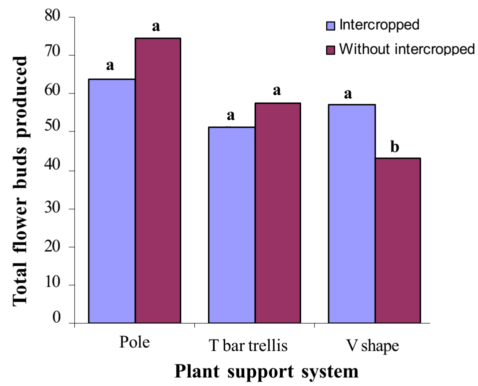

Figure 2. Interaction between the plant support system and intercropped in total flower buds produced/plot.

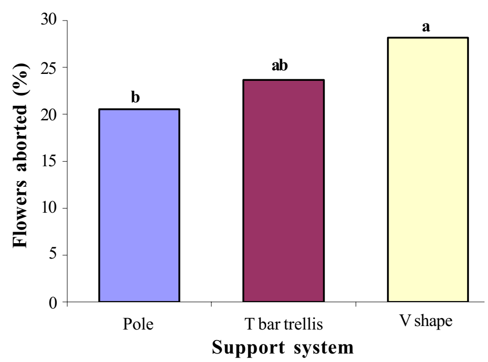

Figure 3. Effect of support systems on percentage flowers aborted.

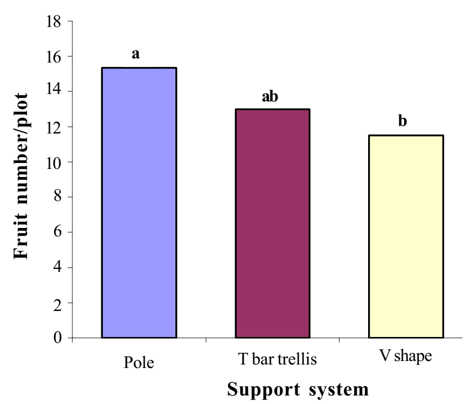

Figure 4. Effect of support systems on fruit number.

plot was also significantly higher in the pole system compared with the T bar trellis and V shape systems (Fig. 5). The highest total fruit weight was 5217 g obtained from the pole system, while V shape and T bar trellis systems gave almost similar values of 4221 and 4205 g, respectively. Based on these values the extrapolated yield for one hectare were 2.09, 1.69 and 1.68 t ha^{-1} for pole, V shape and T bar trellis systems, respectively. A similar finding of increased yield using certain support system was also reported by Couvillon and Nakayama [6]. They observed that the yield of 'Concord' grapes grown on a two-wire crossarm (horizontal) trellis was higher than on a two-wire vertical trellis. Similarly a study on 'Thompson Seedless' grapes by Weaver *et al.* [29] reported that the tallest (2 m tall) trellis used resulted in the highest yield of 'Thompson Seedless' grapes, but the use of crossarms did not significantly increase the yield.

On the contrary, Weaver and Kasimatis [28] found that 'Thompson Seedless' vines trained on trellises with crossarms gave the highest yield. Therefore, using crossarms trellises did not increase

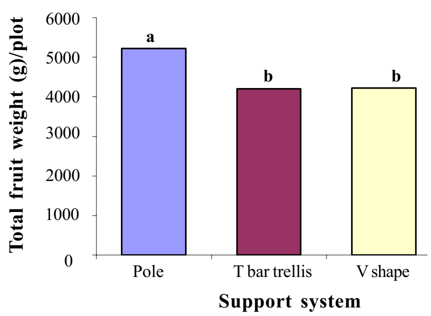

Figure 5. Effect of support systems on total fruit weight.

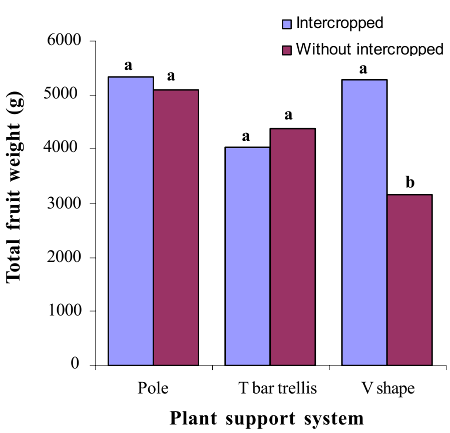

Figure 6. Interaction between the plant support system and intercropping on total fruit weight.

Table 3. Mean on days to fruit maturity and average fruit weight of dragon fruit for three support systems and two planting systems.

System	Days to maturity*	Average fruit weight (g/fruit)*
Support system		
Pole	49.50±0.94	343±17
T bar trellis	48.63±0.82	337±29
V shape	48.88±0.52	370±20
Planting system		
Intercropping	48.50±0.66	363±12
Without intercropping	49.50±0.57	337±22

Differences were not significant at P>0.05 *Mean±S.E

the yield of some cultivars because of a lack of light penetration in the interior of the vines which limited fruit bud differentiation and light exposure of shoots, especially the portions [3]. Another way that could be used to increase yield of 'Thompson Seedless' grapes was through reduced shoot crowding through extension of canopy length and reducing the number of nodes per unit canopy length [22]. They suggested that the low amount of solar radiation penetrating the canopy on a standard T-trellis was a major factor limiting production of the grape.

Photosynthetically active radiation (PAR) is one factor which influences yield. This was concluded by Morsi *et al.*[16] when they found the PAR absorbed by the foliage and that was available for absorption by the fruit differed among the three trellising treatments tested (V type, Tatura trellis and Standard two wires trellis). The highest PAR absorbance was not obtained by the standard canopy but was significantly affecting yield. However, Baldwin [1] found no difference in 'Sultana' yields due to six T-trellis treatments, but the three pruning levels imposed did result in significant yield differences.

In planting of red raspberry, the V-trellis showed increase in yield over the hedgerow system [8]. However, V-trellis system could have several disadvantages such as causing shading of the canes which led to early leaf abscission, favoring the development of fungal disease [26] and lateral fruiting could grow toward the center of the canopy, making harvesting difficult. In this study, the early result indicated significant effects of three types of support systems: pole, T bar trellis and V shape on the yield of dragon fruit in the first year of planting. There was significant interaction ($P<0.05$) between support systems and intercropping on total fruit weight (Fig. 6). In the V shape system, total fruit weight was significantly higher with intercropping compared to sole crop but not in the pole and T bar trellis systems. There was no difference between intercropped and sole crop systems. The residual effect of slower decomposition of long bean litter on nutrient intake as explained in the measurement of number of flower buds produced may have a prolonged the beneficial effect on the total fruit weight.

Days to fruit maturity and average fruit weight: It was recorded that it took 48 to 49 days for the fruit to mature from the onset of flower bud development (Table 3). Support system did not influence the days taken to fruit maturity. Similarly, a comparison between the monocropped and intercropped dragon fruit showed that there was no significant effect of intercropping on days to maturity. Average fruit weight ranged from 337 g/fruit for the T bar trellis system to 370 g/fruit for the V shape system (Table 3). There was no significant effect of support system on average fruit weight. The commercial growers classified size of dragon fruit by three grades: large size (Grade A) with fruit weight of more than 450 g, medium size (Grade B) with fruit weight between 350 to 450 g and small size, (Grade C) with fruit weight between 200-350 g.

Similarly, the findings of Chery *et al.*[5] that training system (Slender spindle, Geneva Y trellis and Tall spindle) and plant density had little effect on average fruit weight of apple. This study was conducted to test on varying density with constant rectangularity of apple on tree yield, fruit size, and fruit color development in three training systems over ten years.

Fruit quality of dragon fruit

Fruit diameter, fruit length, fruit pH and titratable acidity:

Harvested fruit was measured for its diameter, prior to conduct of other tests on fruit quality. There was no significant difference in fruit diameter due to pole, T bar trellis and V shape systems and whether the dragon fruit plants were intercropped or not with long bean. The fruit diameter ranged from 80.42 to 81.87 mm.

Different support systems in combination with or without intercropping with long bean gave no significant effects on fruit length of dragon fruit. Average fruit length ranged from 9.70 to 9.98 cm for the support system. This result showed fruits of different weight gave the same average fruit length.

The pH of fruits taken from the three support systems ranged from 4.75 to 4.84 for the support system. There was no significant effect of support systems or intercropping on fruit pH after 14 months of planting of dragon fruit. However, Morsi *et al.* [16] in their study on type of trellis effects on radiation, absorption and must (grape juice before fermentation is complete) composition of 'Petite Sirah' found that higher pH in the musts was produced from the fruits of the standard two-wire trellis and this was consistent with results of Smart *et al.* [24]. The mean pH for the vertical canopy was significantly lower than that for the standard canopy, but there was no significant difference for berries from inclined and standard canopy.

A similar trend was reported by Palmer *et al.* [18] and Swartz *et al.*[27] who found that in the first year of planting of red raspberry, the fruits obtained from shift-trellis were lower in sugar level and had higher pH than the V-trellis. This was postulated to be due to the low level of light reaching the inner fruit as they matured. They also concluded that the improved light environment in the trellising system led to increased fruit quality.

Titratable acidity of dragon fruit ranged from 0.01 meq g^{-1} for V shape to 0.02 meq g^{-1} for pole system. Intercropping treatment or support system had no significant effects on titratable acidity. This result was consistent with the finding reported by May *et al.* [12] who found that the widening trellis system did not significantly affect Brix of the juice, pH, and acidity of the wine in grapevine. However, they found that acidity tended to decrease and sugar concentration tended to increase with increasing yield. Similar results were also observed by May *et al.* [12] who found the concentration of sugars and acids and the mean berry weight in 'Crouchen' were unaffected by trellis width (0.3 to 1.4 m) and pruning treatment.

Soluble solid concentration: Soluble solid concentrations (SSC) of dragon fruit were significantly higher in the pole and T bar trellis compared to V shape system. T bar trellis system had the highest SSC of 15.50%, followed by pole system with 15.38% and V shape system showed the lowest percentage of SSC with 14.41% (Fig. 7). The measurement of SSC indicated the level of sweetness of the fruit. The higher level of % Brix would show the sweetness of the fruit. However, there was no significant effect of planting systems on soluble solid concentration (% Brix). Decreasing SSC in dragon fruit supported by V shape support system might be because of the design of the V shape system which made the branches overlap more on each other, thus increasing shading that affected fruit development [11] reported that the values for Brix and titratable acidity were higher for 4-wire trellis compared to single-wire trellis.

This finding was supported by Barritt [2] who reported that fruit growing in the shade tended to be poorly colored, small and low

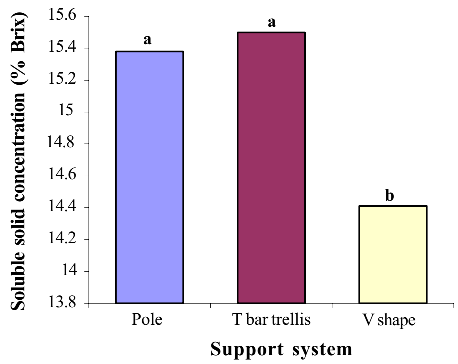

Figure 7. Effect of support systems on soluble solid concentration of dragon fruit.

in soluble solids. These results were different from those reported by Harry *et al.* [9] who showed that in thornless blackberry no significant difference was observed in fruit weight, percentage of soluble solid or percentage of full sun in floricance canopies (at 1 m height) in V trellised plants given various dormant pruning treatments. Steinhauer and Bowers [25] also reported that Brix and yield of 'Cabernet Sauvignon' grapes were not significantly different in three trellis systems (two, four and six wire).

In contrast, Hedberg and Raison[10] concluded that the tendency for 'Shiraz' vines with close rows to have lower Brix than wider-spaced and trellised vines was related to the shaded horizontal canopies that developed.

Peel and flesh color: There were no significant differences in L*, C* and h^0 value of peel and flesh color of dragon fruit among the pole, T bar trellis and V shape systems with or without intercropping. The peel L* values ranged from 31.15 to 32.99 for peel color and 32.73 to 32.93 for flesh color of dragon fruit for the support systems. The C* and h^0 values of peel ranged from 27.02 to 27.66 and from 7.95 to 8.22, respectively. L* values for peel and flesh color were in the range of dark zone. The value of C* for peel indicated quite low in intensity of color and h^0 value indicated it was red in color. Similar results of non-significant effects of support systems and intercropping on flesh color were observed as shown by C* and h^0 values which indicated quite low intensity and was still in the red color zone. This result was similar to that found by Chery *et al.*[5] who reported that color development on 'Gala' apple was not affected consistently by either density or training system. This was also in agreement with the findings of Meland and Hovland [13], who remarked that fruit size and color of 'Summerred' were not influenced by training system. Similar finding was documented for other variety of 'Summerland McIntosh' but no consistent differences were found among treatments as measured by the proportion of fruit not ready for harvest until the last pick. Palmer and Warrington [19] related the needs of sunlight in color development, which indicated the necessity of adequate sunlight within training system in order to maintain high colored fruit in apple production systems. Mika *et al.*[14] also reported that color was believed to be more sensitive than fruit size to light environment.

Conclusions

The use of three support systems: pole, T bar trellis and V shape, was found not to have any significant effect on the vegetative growth of dragon fruit. The results of this study indicated that the pole system was superior in terms of its design. The pole system when used to support dragon fruit showed advantages during the reproductive stage of the main crop. A higher total number of flower buds, total fruit number and total fruit weight were detected with the pole system as compared to the T bar trellis and V shape systems.

The pole system resulted in a significantly lower percentage of flowers aborted compared to the V shape system. Pole and T bar trellis systems produced fruits with significantly higher soluble solid concentrations compared to V shape system. However, diameter of stem, chlorophyll content of stem, duration of fruit maturity, yield of long bean and average fruit weight of dragon fruits were not affected by the type of support system used. Similarly there was no significant effect of support system on fruit quality as measured by fruit diameter, fruit length, fruit pH, peel and pulp color and titratable acidity. Furthermore, for total flower buds produced and total fruit number, there was a significant interaction effect between support systems and intercropping.

The design of pole and T bar trellis systems with vertical poles and top frames allowed the branches and fruits of dragon fruits to be more exposed to sunlight. Such a design also resulted in a lesser number of overlapped branches, thus creating less inter shading of the branches. The branches were able to spread out over the top frames. Both systems also made the weeding of unwanted plants easier around the bases of the main poles. The slanting side poles in the V shape system hindered weeding movement. From field observation it was found that the pole system had an advantage of easier management in branch pruning and fruit harvesting.

The inclusion of intercropping of long bean during the first year of planting of dragon fruit did not affect dragon fruit growth and yield parameters except for total flower buds produced and total fruit weight of dragon fruit. The idea of intercropping long bean with dragon fruit was based on the premise that both crops could use the same support system to hold their stems and branches while the dragon fruit plant was still at an immature stage producing a limited number of branches. Thus intercropping of dragon fruit with long bean if practiced during early planting period of dragon fruit was not harmful to the growth of the main crop and it can give additional income from long bean.

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