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Productivity and Fruit Quality of Red-fleshed Dragon Fruit, *Hylocereus polyrhizus* (Britton and Rose) under Jasaan Series

Nelda R. Gonzaga, Apolinario B. Gonzaga, Jr., Renante D. Taylaran, Rainier T. Pajinag, Rosalito A. Quirino

College of Agriculture, University of Science and Technology of Southern Philippines – Claveria Moscat, Claveria, Misamis Oriental 9004
Corresponding Author: Apolinario B. Gonzaga, Jr., email: apolgonzaga78@yahoo.com

Abstract

Red-fleshed dragon fruit (*Hylocereus polyrhizus* Britton and Rose) is a newly introduced cacti crop species in Claveria, Misamis Oriental, Northern Mindanao with a lot of potentials for fresh, processed, medicinal and industrial uses. The crop agronomy including its nutrient management is still not very known under the local agroecosystem. This study aimed to determine the growth, fruit quality, and economic efficiency of growing red-fleshed dragon fruit. Specifically, it sought to determine the NPK levels suitable under the Claveria conditions. Different levels of nitrogen (N), phosphorus (P), and potassium (K) [T_1- 120-120-120 (N-P_2O_5-K_2O), T_2-120-60-60, T_3- 60-120-60 and T_4-60-60-120] serving as treatments were established under Jasaan series. Results showed that the individual fruit weight was enhanced by the application of more N (T_2- 120-60-60) relative to other nutrient combinations. Balanced application of nutrients (T_1) resulted in the highest fruit yield (22 t/ha), and the highest fruit quality (^{0}Brix) was measured at T_3. Economic efficiency also indicates less application of N and P with more of K (T_4) resulted in higher Return on Investment (ROI). This study may provide information to the local crop growers on the nutritional requirement of the fruit as the baseline to further improve its agronomy under the local conditions in Claveria.

Keywords: agronomy, cacti, nitrogen, phosphorus, potassium

Introduction

Red-fleshed dragon fruit (*Hylocereus polyrhizus* Britton and Rose) is a climbing fast growing perennial vine cactus species that originated from Mexico, Central and South America (Mizrahi et al., 1997). This tropical fruit is also known as prickly pear or strawberry pear or 'pitahaya' or 'pitaya' (Jaya, 2010) and belongs to the family Cactaceae (Hart, 2005). The red-fleshed variety is rich in antioxidants as well as beta-carotene, lycopene, vitamin E, vitamin C, phosphorus and calcium that help in developing healthy bones, teeth and skin (Mizrahi et al., 1997). Moreover, it also contains essential fatty acids, i.e., 48 % linoleic acid, and 1.5 % linolenic acid in black seeds (Ariffin et al., 2009). Similarly, it is a potential source of betalins for the food industries (Viñas et al., 2012).

Similar with other cacti families, vegetative propagation is the mode of reproduction for the red-fleshed dragon fruit. The variety grows well at a high temperature of up to 38 to 40 ^{0}C but fails to flower at this temperature range (Nerd et al., 2002; Le Bellec et al., 2006). This fruit variety is very efficient in using water because it is capable of using the CAM (Crassulacean Acid Metabolism) photosynthetic pathway (Mizrahi & Nerd, 1999; Mizrahi et al., 2007). With these physiological characteristics, it is mostly grown on marginal lands in the tropics requiring relatively low inputs of water and fertilizer. Such attributes have made the plant attractive for small-scale farms in Mexico (Pimienta-Barrios & Nobel, 1994).

As a newly introduced crop species in the Philippines very little has been published about the fertilization of this plant. Merten (2003) articulated that a proper schedule will need to be worked out to increase flowering and fruit production. As also reported, dragon fruit responds well to most fertilizers, although care must be taken not to burn the shallow root system. To date, no systematic research has been performed on irrigation and fertilization requirements. In the meantime, Mizrahi and Nerd (1999) recommend that the climbing cacti be irrigated with 150 mm water per year and fertilized with 35 parts per million (ppm) nitrogen (N) from 23-7-23 (NPK) fertilizer levels.

Report of Thomson (2002) in California revealed that animal manures and composts had been used successfully as the source of the fertilizer. In Taiwan, Zee et al. (2004) reported a fertilizer program included well-composted steer manure at 9.0 lb per plant every four months starting in April, supplemented with 3/12 oz/plant of a commercial 13-13-13 fertilizer. Research works also provided evidence for the need of fertilization, which tested the effect of mineral application and CO_2 enrichment on these vine-cacti (Nobel & De la Barrera, 2002; Weiss et al., 2009). Further, the misconception of the common belief that CAM plants do not respond positively to CO_2 was proven several times (Nobel & De la Barrera, 2004; Raveh et al., 1995; Weiss et al., 2010). Carbon dioxide enrichment could enhance growth and production of both vegetative and reproductive organs (Weiss et al., 2010). The farmer's recommendation is to apply 23-7-23 NPK added with microelements with any irrigation containing around 70 ppm pure N (Mizrahi, 2014).

The crop can best adapt to loamy, sandy or rocky soils with good drainage (Barbeau, 1990). There are different recommended doses of fertilization for this plant. In Israel, Weiss et al. (1994) and Mizrahi and Nerd (1999) suggest 20-20-20 and 23-7-23 (NPK), respectively. The plant requires mineral fertilization, especially when annual yields are high between 20 to 45 tons/ha. However, the specific demand for the various mineral nutrients is unknown because data on mineral fertilization needs are lacking (Mizrahi, 2014).

The most significant advantage of this crop is that once planted, it will grow for about 20 years and one hectare could accommodate 1000-2000 plants and attain in full production within five years (Chakma et al., 2014). The plant produces fruit in the second year after planting and attains full production within five years. Gunasena et al. (2007) considered it the fruit of the future and widely used as juice and in fruit salads at restaurant (Luders & McMahon, 2006).

In the Philippines, dragon fruit is becoming a favorite of many Filipinos for its known therapeutic properties. Moreover, the fruit is now considered as "healthy food for the table", because of low calories but rich in fiber and minerals (Le Bellec et al., 2006; Khalili et al., 2006). The fruit is now gaining popularity and will eventually pose a high demand among local consumers. It is, therefore, becoming an emerging champion in the local fruit industry. Pascua et al. (2013) reported that in Ilocos Norte under Type 1 climate, this dragon fruit can be excellently grown owing to both climatic and soil conditions of the province. Moreover, the same authors revealed that it could even grow in marginal upland and dune areas which are abundant in Ilocos Norte.

Presently, this experiment is the first study conducted involving the species as an experimental crop in Claveria, Northern Mindanao. Soil materials are classified as acid upland soils classified as fine mixed isohyperthermic, Ultic Haplorthox (Mercado, 2007). The soil series dominating the landscape is Jasaan Series with Jasaan clay loam and Jasaan clay as the dominant soil type. Jasaan Series belongs to Order Oxisol. Other Orders found in the area are Inceptisols and Alfisols (Maglinao, 1998). Soil erosion rate is 200-350 mg ha^{-1} yr^{-1} (Fujisaka et al., 1995; Mercado, 2007). Average annual precipitation is 3000 mm that is distributed throughout the year and usually peaks during June and October.

Yields vary as a function of the nutritive elements supplied. The dragon fruit root system is superficial and can rapidly assimilate even the smallest quantity of nutrients. Mineral and organic nutrition are particularly advantageous, and when they are combined, their effect is even more beneficial (Le Bellec, 2003). There are few studies conducted on the nutritional requirements of this fruit under the local condition being a newly introduced species in the Philippines. Hence, this study aimed to determine the growth, fruit quality, and economic efficiency of growing red-fleshed dragon fruit. Specifically, it sought to determine the recommended NPK level suitable under the Claveria, Northern Mindanao conditions. This study may provide information to the local growers on the nutritional requirement of the crop as the baseline to further improve its agronomy under the local conditions in Claveria.

Materials and Methods

The study site was at the University of Science and Technology of Southern Philippines (USTP) (formerly MOSCAT, 80 36' 36.9" N, 1240 52' 59.9" E). This study used the Randomized Complete Block Design consisting of four different levels of NPK fertilizers: T_1- 120-120-120 (N-P_2O_5-K_2O), T_2- 120-60-60, T_3- 60-120-60 and T_4- 60-60-120, respectively. Three support posts (5 feet and 6 inches each) per treatment per replication were installed. A total of 36 posts planted with four cuttings (50-65 cm) were established at the study site (Figure 1). The soil is classified as silty clay, relatively flat and classified under Jasaan Series (an Oxisol). The soil has a pH of 6.01, 4.18 % organic matter, 7.98 ppm extractable phosphorus, and 174 ppm exchangeable potassium (based on the results of soil analysis done before the conduct of this study).

At planting date (July 30, 2014), twelve kilograms (dry weight basis) of well-decomposed cow manure were added as the basal fertilizer applied using a ring method of application per post. Support pillars or posts were spaced at 3 m x 3 m (1,111 posts/ha). Cuttings used as planting materials (also known as the segment) were each tied with plastic straw to prevent it from toppling down. Support posts were installed with metals (two pieces), placed horizontally, and a used motorcycle tires were installed per post, respectively.

Figure 1. **a – Experimental set-up at 5 MAP; b – a blooming plant at night; c – single flower at anthesis and; d – a fruiting single segment in its fruiting stage, respectively.**

Scheduled monitoring of pests and diseases and periodic ring-weeding were done throughout the one-year cycle. Moreover, emerging water sprouts were pruned and not allowed to grow. At the start of the planting, newly planted cuttings were irrigated with tap water. Applications of different NPK levels as fertilizers (T_1- T_4) were applied every 30^{th} day of the month, starting a month after planting (MAP). Regular pruning of emerging water sprout was done. Similarly, pests and disease monitoring were also conducted regularly. A ground cover (*Arachis pintoi*) was planted at the 6th MAP.

The growth and the quality of the dragon fruit were determined, and the economic efficiency was then evaluated. The growth parameters such as individual fruit weight (g), shoot length (cm), number of shoots (counted after the individual cutting or plants have reached and suspended on the used tires as training support), days to 1st flowering, average number of fruit/post, and fruit yield (t/ha) were measured. The fruit quality was determined based on its TSS content expressed in ^{0}Brix of the fruit. Brix is a measure of the sugar content or percent solids in a given weight of plant juice (Rane et al., 2016). The prevailing market prices of materials and labor costs were used to compute for Return on Investment (ROI) in determining the economic efficiency of the fruit.

Results and Discussion

A. Growth parameters

Individual fruit weight (g)

The varying NPK levels influenced the individual fruit weight (g) with T_2 (120-60-60-, N-P_2O_5-K_2O) yielding the heaviest weight (429.4 g) as shown in Figure 2. In contrast, T_3 recorded the lightest/smallest fruit weight (363.4 g) among the four NPK treatments. Report of Chakma et al. (2014) also showed a similar trend, wherein the higher N applied resulted in bigger and heavier fruit in the test crop. Tri et al. (2000) observed similar results in Vietnam.

Nitrogen plays a pivotal role in many physiological and biochemical processes in plants having a more significant influence on growth and yield of crop plants than any other essential plant nutrients. This nutrient is a component of many essential organic compounds ranging from proteins to nucleic acids. This constituent of the chlorophyll molecule plays an important key role in plant photosynthesis (Fageria, 2008). Additionally, N fertilization affects yield and quality traits for processing such as total solids, soluble solids, reducing sugar and acidity (Colla et al., 2003).

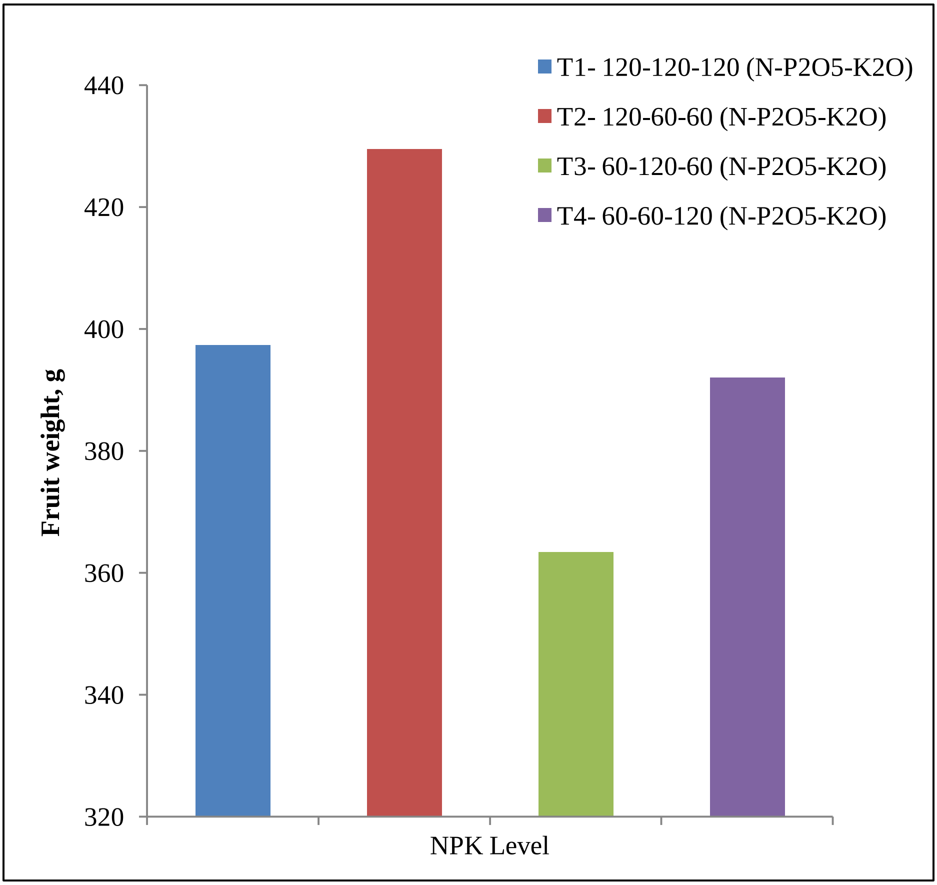

Figure 2. Individual weight (g) of red-fleshed dragon fruit under different NPK levels.

Shoot length (cm)

The influence of the varying NPK levels on the growth and flowering of red-fleshed dragon fruit under Claveria condition is shown in Table 1. All NPK levels imposed as treatments indicated a similar effect on the shoot length or also known as the segment. The result suggests that any of the nutrient level imposed as the variable can induce growth (shoot length) pending consideration of the economic cost.

The result of Jaya (2010) reflects similarity in the shoot length in his study in Indonesia. The genotypes especially the red-fleshed cultivar is known to respond positively to the application of fertilizer as shown in its vigorous and luxuriant growth, 2-3 weeks after application of nutrients (Pushpakumara et al., 2005).

Table 1. Influence of the varying NPK levels on the growth and flowering of red-fleshed dragon fruit under Claveria condition.

Treatments (kg ha^{-1} N-P_2O_5-K_2O)	Shoot Length (cm)	Number of Shoots	Days to 1st Flowering
T_1- 120-120-120	112.15	15.65	09 May 2015(282 DAP)
T_2- 120-60-60	109.00	14.46	08 May 2015(281 DAP)
T_3- 60-120-60	119.61	14.54	07 May 2015(280 DAP)
T_4- 60-60-120	110.14	15.79	07 May 2015(280 DAP)
Mean	**112.82**	**15.11**	
LSD (0.05)	**11.89**	**2.38**	
CV (%)	**8.56**	**12.50**	

DAP- Days after Planting

Number of shoots

The treatment with a higher level of K (T_4-60-60-120) had the most number of shoots. However, the number of shoots is relatively similar for all the treatments imposed. The number of shoots in dragon fruit is critical in fruit production; hence initiation of flower primordial originates in the shoot system of dragon fruit (Mizrahi, 2015).

Days to 1st flowering

The number of days to 1st flowering ranges from 280-281 days after planting (DAP) or about eight months after planting or field establishment of the crop. This result demonstrates that dragon fruit can be successfully grown in Claveria, Misamis Oriental with similar gestation period from other production sites. Results of Chakma et al. (2014) also showed comparable gestation period. In this experiment, the first sign of flowering was recorded in early April 2015 and then declined during November 2015. Results of Pushpakumara et al. (2005)

in Bangladesh showed an almost similar trend, although flowering in their study extends up to early December.

Average number of fruit per post

Table 2 shows the influence of the varying NPK levels on the yield and qualitative character (Total Soluble Solids) of red-fleshed dragon fruit under Claveria conditions. The highest number of fruit was harvested from T_1 (31.70), followed by T_3 (30.40), and the less number of fruit/post was recorded at T_2 (27.20). However, the mean number of fruit per post harvested indicates similarity of effects among the imposed varying NPK levels. There was no trend observed relative to the parameter measured and the levels of nutrient inputs. The quantity of fruit per post is a critical yield parameter influencing yield per unit area in dragon fruit. Moreover, the result suggests that any of the nutrient levels applied as treatments can be recommended pending consideration of the production costs, especially on the added fertilizer materials.

Table 2. Influence of the varying NPK levels on the yield and qualitative characters of red-fleshed dragon fruit under Claveria, Northern Mindanao condition.

Treatments (kg ha^{-1} N-P_2O_5-K_2O)	Number of Fruit Per post	Fruit Yield (tons ha^{-1})	Total Soluble Solids (^{0}Brix)
T_1- 120-120-120	31.70	22.00	12.71
T_2- 120-60-60	27.20	20.90	12.37
T_3- 60-120-60	30.40	17.80	12.93
T_4- 60-60-120	29.00	21.70	12.35
Mean	**29.57**	**20.60**	**12.59**
LSD (0.05)	**13.24**	**13.40**	**1.25**
CV (%)	**36.40**	**5.20**	**7.89**

Fruit Yield (t/ha)

The highest computed fruit yield was recorded at T_1 (22.0 t/ha), followed by T_4 (21.7 t/ha), while the smallest fruit yield was noted at T_3 (17.8 t/ha). However, the fruit yield is relatively similar for all treatments. The yield levels (17-22 t/ha) are comparable to other cultivation areas as stated by several reports (Jaya, 2010; Le Bellec et al., 2006). The application of nutrients regardless of their sources and doses markedly increased the fruit yield in contrast to unfertilized fruit or plant (Maity et al., 2006). In a related study, Monga et al. (2004) also found similar results where the application of NPK fertilizer increased fruit yield of mandarin orange over unfertilized control in India.

B. Quality

Total Soluble Solids (TSS)

The TSS content indicates the sweetness of the fruit (Yusoff et al., 2008). The higher level of ^{0}Brix would show the sweetness of the fruit. Fruits applied with double amount of phosphorus relative to N and K had higher ^{0}Brix value (T_3, 12.93), followed by T_1 (12.71) and the lowest value was recorded at T_2, respectively. Nitrogen application has a negative effect on TSS (Wiedenfeld, 1995). Further reports of Muchow et al. (1996) and Gascho et al. (1986) revealed that soluble solids or sucrose production decrease with the high application of N.

Several researchers have reported TSS of 9 -15 % (white-fleshed variety) and 8-11 % for the red-fleshed variety (Hoa et al., 2006; Esquivel et al., 2007). However, results of this experiment suggest that TSS values are relatively similar. This quality parameter is indicative that dragon fruit production in the experimental site is at far with other production areas that have long been cultivating the species.

C. Economic efficiency

Economic efficiency of dragon fruit production under Claveria condition is presented in Table 3. Balance application of NPK (T_1, 120-120-120) yielded the lowest ROI at 0.61 %, relative to other imposed nutrient levels. Meanwhile, doubling the amount of K_2O relative to N and P_2O_5 (T_4- 60-60-120) recorded the highest ROI (1.58 %). The ROI values indicate return per peso invested, hence a very important parameter in measuring economic profitability. Approximate total costs of investments were all based on the current prevailing market prices at the time of the conduct of the study based on Claveria, Northern Mindanao condition.

Table 3. Economic efficiency of red-fleshed dragon fruit under varying NPK levels under Claveria condition.

Treatments (kg ha^{-1} N-P_2O_5-K_2O)	Gross Income (PhP)	Total Investment* (PhP)	Net Income (PhP)	Return on Investment (%)
T_1- 120-120-120	1,627,990	1,012,010	615,980	0.61
T_2- 120-60-60	2,505,200	1,011,667	1,493,533	1.48
T_3- 60-120-60	2,132,800	1,011,689	1,121,111	1.11
T_4- 60-60-120	2,609,600	1,011,565	1,598,035	1.58

*Computation of material inputs, labor costs and other expenses were all based on the current prevailing costs and on per ha basis, respectively.

The cost of post material constitutes the highest cost of material input (54%). However, the cost can be easily offset. Hence this will be only during the first year of crop establishment, and the crop will start to bear fruits during the second year after establishment. According to Gunasena et al. (2007), the strong post of the dragon fruit served as its lifeblood. The post also acts as a support for the large and numerous branches of this climbing cactus and helps attach its roots. The support structure also facilitates weeding, fertilizing, pruning and harvesting for agronomic management. In Malaysia, Yusoff et al. (2008) reported that the cost of construction for the post is approximately 32% of the initial cost of dragon fruit cultivation. Locally, Ruba (2014, personal communication) also reported the same approximate estimate of the cost of materials and inputs. Notably, in this study, dragon fruit started to bear fruit at about 8th months (May 2014) after planting or crop establishment (July 2014).

Conclusion and Recommendation

Different NPK levels imposed as treatments influenced the individual fruit weight of red-fleshed dragon fruit. However several key growth and quality parameters revealed to be similar across the imposed variables. Hence, this study initially demonstrated that dragon fruit (red-fleshed) could be profitably cultivated and comparable both in production efficiency and quality from other agroecosystems. Related on-going studies are suggested be pursued to determine further and evaluate the other agronomic characteristics of the crop and its corresponding agronomic interventions for sustainable production.

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