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Performance of starfruit cv. B10 under netted structure. I. Effect of crop load on plant physiological performance and yield

(Prestasi belimbing besi kultivar B10 di bawah struktur pelindung. I. Kesan kelebatan buah terhadap prestasi fisiologi dan hasil)

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Key words: starfruit, crop load, physiological performance, yield, specific leaf weight (SLW), stomatal conductance, transpiration

Abstract

Plant physiological performance and yield of starfruit at several crop loads under netted structure were studied in the starfruit farm at MARDI, Serdang, Selangor. The crop load consisted of three treatments ranging from less than 100 to about 600 fruits per tree. Crop load significantly influenced the specific leaf weigh (SLW). The SLW from plants with the lowest crop load were significantly higher than the medium and high crop load. The rate of stomatal conductance and transpiration of mature leaf was significantly affected by the crop load treatments. The stomatal conductance of the high crop load (244.8 mmol $m^{-2}s^{-1}$) and medium crop load (258.2 mmol $m^{-2}s^{-1}$) were significantly higher at p <0.05 compared to the low crop load (133.0 mmol $m^{-2}s^{-1}$). At the same time, leaves at the lowest crop load had the lowest transpiration rate of 2.3 mmol $m^{-2}s^{-1}$ compared to 4.4 and 4.3 mmol m^{-2} s^{-1} at the medium and highest crop load respectively and the difference was significant at p <0.05. The yield increased significantly (p <0.05) with increase in crop load from 6.3 t/ha at the lowest crop load to 22 t/ha at the highest.

Introduction

Crop load or fruit load is actually the gross yield obtained per tree. It has great impacts on dry matter partitioning, fruit growth and yield (Edson et al. 1995; Palmer et al. 1997; Marcellis and Heuvelink 1998; Howell 2001). Palmer et al. (1977) observed that leaf physiological performance of apple plants showed a significant response to crop load. They observed a decrease in leaf assimilation rate of non-cropping trees of 50% or more over the rates of heavy cropping trees. On the other hand, many workers reported inconsistent effect of crop load on leaf photosynthesis (Flore and Lakso 1989; Schechter et al. 1994a, b)

Many factors can affect crop load, such as plant nutrient status, use of growth regulators, pruning and plant form, pollination and fruit set, water and crop management, biennial bearing effect, and pest and disease management.

Starfruit is a heavy bearer. When grown in conventional planting in the open,

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fruit thinning is conducted during fruit wrapping where fruit in clusters, curved fruits and fruits injured by insects are thinned. However when cultivated under netted structure, fruit set improved from 36% in the open to 64% (Zabedah et al. 1999) resulting in increased yield. Starfruit under netted structure has been observed to produce between 400–1,000 fruits/tree/ season. Thinning of fruits under netted structure is minimal. Only curved fruits are thinned while fruits in clusters are usually not thinned and allowed to mature. With such a heavy yield, fruit quality may be affected.

An experiment was conducted to study the effects of crop load on plant physiological performance, yield and size of starfruit. The main objective was to get the optimum yield of starfruit cultivated under netted structure.

Materials and methods

Experimental site and agronomic practice

The trial was conducted in the starfruit plot cultivated under netted structure at MARDI Serdang, Selangor. It was initiated in February 2003. Starfruit plants were induced to flower by pruning the branches and followed by application of high-potassium fertilizer formulation (12:7:24 NPK). When the flowers were blooming, two hives of bees (*Apis cerana*) were introduced into the plot for pollination and fruit set. When the fruit has reached about 3–4 cm size, 18 treatment plants were selected at random. The selected plants were about the same size in terms of trunk diameter and canopy diameter. The three crop load treatments (*Table 1*) were achieved by thinning fruits especially curved and overclustered fruits. Thus, there were six single tree replications for the three treatments, giving a total of 18 treatment plants arranged in completely randomized design (CRD).

Fertilizer at the rate of 720 g N: 315 g P: 1,440 g K per plant per crop cycle was applied in three split applications: after pruning, when the fruits were 2–3 cm long and at stage 2 (*Table 2*) of the maturity index. All trees were irrigated with 20–25 litres of water daily, except on rainy days where a low sprinkler irrigation system was used. At full bloom, the plants were sprayed with a mixture of fungicide and insecticide. The fungicide used was benomyl (2 g/4.5 litres) to control anthracnose fruit spot, while the insecticide used was cypermethrin (6 ml/4.5 litres) to control flower moth.

Table 1. The crop load levels

Treatment no.	Crop load	Fruits/tree
1	Low	<100
2	Medium	200–300
3	High	500–600

Table 2. Description of the maturity index of starfruit using colour score

Maturity index	Colour
1	Whole fruit is green
2	Whole fruit is light green
3	Fruit is yellowish-green
4	Fruit is greenish-yellow
5	Whole fruit is yellow
6	Whole fruit is orange

Leaf physiological parameters

Leaf development was monitored in terms of specific leaf weight and reducing sugar concentration. Simultaneously, leaf physiological performance such as stomatal conductance and transpiration was also monitored.

The leaf development was monitored during the last six weeks of fruit development period. About 30–40 newly emerged shoots during this period were tagged at random around the treatment plants. Since starfruit has compound leaf with leaflet number varying between 9, 11 and 13, only leaves with 11 leaflets were tagged for monitoring. Four leaves were sampled per treatment per replication.

The leaf physiological performance such as stomatal conductance and transpiration was measured using a LI–1600 steady state Porometer (Li–Cor, Inc., NE, USA). The readings were taken between 8.30–10.30 a.m. The leaves were then detached and placed in a moist plastic bag separately, and brought back to the laboratory for determination of specific leaf weight.

For leaf reducing sugar concentration, the leaf samples of mature leaf (35-day-old leaves) were sampled at four stages of fruit maturity index (stage 1–4) and after fruit harvest. The procedure by Somogy (1951) was used in determining the leaf reducing sugar concentration. The leaf reducing sugar concentration was calculated according to the procedure by Segel (1976).

Gross yield

The fruits were harvested when they reached maturity index 3–4, stages for export to Europe (maturity index is shown in *Table 2*). Every fruit was harvested from each tree, the number counted and total weight of fruit per tree was recorded using a top-pan balance. The fruit weight was measured soon after fruit harvesting.

Experimental design and statistical analysis

The experimental design used was completely randomized design replicated six times. Data was subjected to analysis of variance using SAS package. The least significant difference (LSD) test was used to test differences between treatment means.

Results and discussion

Stomatal conductance and transpiration

The stomatal conductance, in the range of 105–152 mmol m^{-2} s^{-1} for younger leaves (21 days old), increased with leaf age (*Figure 1*). The effect of crop load on leaf stomatal conductance on 21 and 28-day-old leaves were not significant. However, the effect of crop load on stomatal conductance of mature leaves (35 and 42-day-old leaves) was significant (p <0.05). At 35 days old, the stomatal conductance of high and medium crop loads was 83–93% higher than the low crop load. The difference between treatments was not significant on 56-day-old leaves.

Generally, leaf transpiration rate increased significantly as leaf age increased from 21 to 28 days old, but was not significantly affected by the crop loads (*Figure 1*). Similarly, the effect of crop load on leaf transpiration rate was significant on 35 and 42-day-old leaves. At 35 days old,

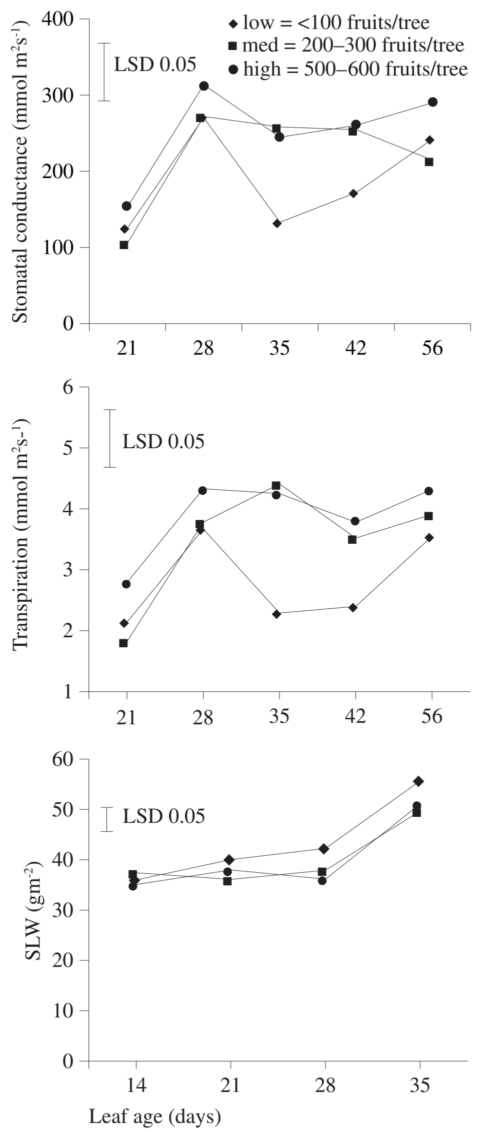

Figure 1. The effect of crop load on leaf stomatal conductance, transpiration rate and specific leaf weight at various leaf ages

the leaf transpiration rates of the medium and high crop loads were 91% higher than the lowest crop load (p <0.05). The transpiration rate of 56-day-old leaves was not significantly affected by the crop load.

Specific leaf weight (SLW)

When the leaves were young (14 and 21 days old), the SLW was not significantly influenced by the various crop loads. However as the leaves reached 28 and 35 days old, the crop load significantly influenced the SLW. The SLW of 35-day-old leaves of the medium and high crop loads were significantly lower than the low crop load at p <0.05 (*Figure 1*). The result indicated that mature leaves of the low crop load had higher leaf reserves than the high and medium crop loads. The SLW increased with leaf age where the SLW of 14-day-old leaves increased by 48% as the leaf reached 35 days old.

Reducing sugar concentration

The reducing sugar concentration of 35-day-old leaves at various stages of maturity and after fruit harvest is shown in *Figure 2*. At all maturity index, the leaf reducing sugar was highest for the low crop load (p <0.05). After fruit harvest, the difference in the leaf reducing sugar concentration between the crop loads was not significant. The data

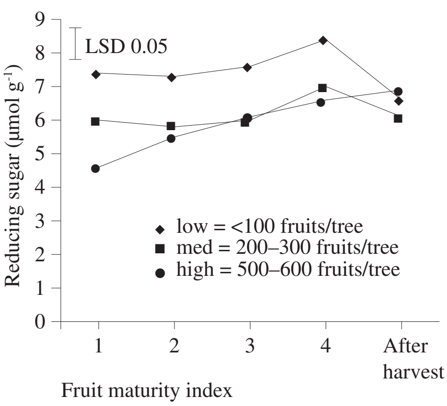

Figure 2. The effect of crop load on leaf reducing sugar concentration at various fruit maturity index and after harvest

indicated that crop load can significantly influence the leaf reducing sugar concentration where plants with low crop load probably had higher reserves (soluble sugar and starch).

The leaf stomatal conductance and transpiration study at the various crop loads was conducted because it was expected that they were proportionally related to photosynthesis of starfruit. This is based on the result of work carried out by Mohd Razi and Muhammad (1992) and Izham (1994) on starfruit. Both the leaf stomatal conductance and transpiration were low on young leaves (20 days old) and were not affected by crop loads indicating that they have very low photosynthetic rates. This is probably because the young leaves were still sinks and respiration rate was higher than photosynthesis as reported by Flore and Lakso (1989). The result is also in agreement with the findings of Schaper and Chacko (1993), where stomatal conductance and photosynthesis were low on 2-week-old avocado leaves, since they have few and underdeveloped stomata (Liu et al. 1999). The crop load effect on stomatal conductance, transpiration and hence photosynthesis rate on older leaves indicated that the role of leaves were no longer sinks but has shifted to source as they matured. The higher stomatal conductance of the high and medium crop loads indicated the higher demand for assimilates.

The leaf reducing sugar concentration of mature leaves (35 days old) of low crop load were 25–32% higher than medium or high crop loads. The higher leaf reducing sugar concentration in the leaf tissues of low crop load had possibly contributed to the significantly higher specific leaf weight (35-day-old leaves). The result is in agreement with Shimizu et al. (1975) and Goldschmidt and Golomb (1982) who observed that crop load has large overriding effects on carbohydrate levels in most tree organs.

The lower SLW (35-day-old leaves) and leaf reducing sugar concentration of the high and medium crop load tree also suggested that photosynthates were used for the high number of developing fruits which served as active sinks. After harvest when active sinks (such as fruits) were no longer present, there was no significant difference in the leaf reducing sugar concentration of the various crop loads. Palmer et al. (1997) observed that the increase in SLW of light and non-cropping trees was due to build up of starch within the leaf tissue as a result of low demand of assimilates for the low crop load.

Gross yield

The gross yield is the total fruit weight per tree. The yield increased significantly with increase in crop load from 6 t/ha (21 kg/tree) at the lowest crop load to 22 t/ha (74 kg/tree) at the highest crop load (*Figure 3*). For the conventional planting in the open field, farmers usually maintain approximately 150–200 fruits/tree/harvest. Comparing yield of conventional planting to the high crop load (500–600 fruits/tree/harvest), the yield increased by 85% with increase in crop load.

Increase in crop load resulted in significant increase in gross yield, where there was a 250% increase in gross yield from the low crop load to the high crop load. Thus, the higher rates of stomatal conductance and transpiration and hence photosynthesis of the high crop load leaves were to meet the higher demand for photosynthates by the high crop load trees. Such increase in gross yield with increase in crop load was observed by Dokoozlian et al. (1998) on Redgold grapevines. Similar observation was made by Palmer et al. (1997) and Pallas et al. (2001) who observed a linear pattern of increase in yield with increasing crop load.

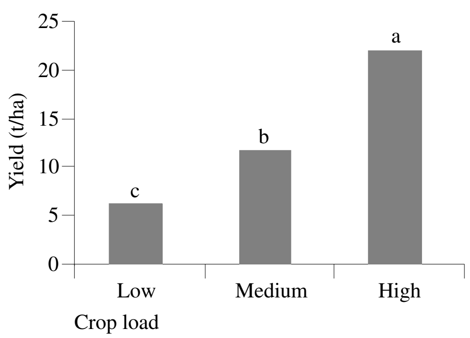

Figure 3. The effect of crop load on yield of starfruit. Values followed by different letters are significant at p <0.05 by LSD

Conclusion

Crop load has a significant influence on the plant physiological performance and yield of starfruit. Leaf physiological performance such as stomatal conductance and transpiration increased with increase in crop load indicating the higher sink demand by the plants with the medium and high crop loads. Gross yield of starfruit significantly increased with increase in crop load. The yield increased significantly from 6 t/ha at the lowest crop load to 22 t/ha at the highest crop load.

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Abstrak

Kesan kelebatan buah terhadap fisiologi tanaman dan hasil belimbing besi di bawah struktur pelindung telah dikaji di ladang belimbing MARDI, Serdang, Selangor. Sebanyak tiga tahap kelebatan buah telah dikaji, iaitu antara kurang daripada 100 biji hingga 600 biji buah sepokok. Kelebatan buah amat mempengaruhi berat spesifik daun (BSD). BSD bertambah dengan ketara pada pokok yang buahnya kurang lebat berbanding dengan sederhana lebat dan sangat lebat. Kelebatan buah juga amat mempengaruhi kadar koduktans stomata dan kadar transpirasi daun matang. Kadar konduktans stomata lebih tinggi pada pokok yang sangat lebat (244.8 mmol m^{-2} s^{-1}) dan sederhana lebat (258.2 mmol $m^{-2}s^{-1}$) berbanding dengan pokok yang kurang lebat (133.0 mmol m^{-2} s^{-1}) (p <0.05). Kadar transpirasi daun terendah juga berlaku pada pokok yang kurang lebat, 2.3 mmol m^{-2} s^{-1}, berbanding dengan 4.4 dan 4.3 mmol m^{-2} s^{-1} pada pokok sederhana lebat dan sangat lebat (p <0.05). Hasil belimbing bertambah dengan ketara daripada 6.3 t/ha pada pokok yang kurang lebat kepada 22 t/ha pada pokok yang sangat lebat.

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