

Performance of starfruit cv. B10 under netted structure.

II. Effect of crop load on exportable yield, fruit size, fruit physical and chemical properties

(Prestasi belimbing besi kultivar B10 di bawah struktur pelindung. II. Kesan kelebatan buah terhadap hasil boleh eksport, saiz buah, ciri fizikal dan kimia buah)

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Key words: starfruit, crop load, fruit quality, fruit size, fruit physical properties, fruit chemical properties

Abstract

Exportable yield and fruit size of starfruit at several crop loads under netted structure were studied in the starfruit farm at MARDI, Serdang, Selangor. Increase in crop load resulted in increase in number of small (S) and medium (M) size fruits. The exportable yield also increased from 50% at the lower crop load to 75% at the high crop load ($p < 0.05$). The number of exportable S and M increased from 1 box/tree at the low crop load to 13 boxes/tree and 7–8 boxes/tree respectively at the highest crop load ($p < 0.05$). Very small fruits (VS) and extra large fruits (XL) which constitute as reject fruits were significantly influenced by the crop load treatments. The number of VS fruit reached 141 fruits/tree at the highest crop load. A reverse trend was found for the number of XL fruits/tree. Fruit density and fruit firmness were not significantly influenced by the crop load treatments. The fruits of the low crop load had significantly higher wing tip thickness ($p < 0.05$). Fruits of the lowest crop load had the highest width of wing base ($p < 0.05$). However, vitamin C and total soluble solid content were not significantly influenced by the crop load treatments.

Introduction

Crop load, which is the gross yield obtained per tree, can influence marketable yield, size and other fruit qualities (Collins and George 1997; Palmer et al. 1997). Under most conditions, fruit trees will set more fruits than needed for a full crop. If this heavy set of fruit is maintained throughout the fruiting season, it will usually result in low quality fruits and alternate bearing.

The importance of crop load was recognized in the early 1900s. Apple growers and researchers realized that fruit thinning to a suitable crop load not only promoted annual bearing, but also increased fruit size and colour, increased tree vigour and reduced limb breakage and winter injury.

Usually yield is inversely related to fruit size. Persimmon trees with high fruit load usually produce high yield of small

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fruits in the first season followed by low yield of larger fruits in the next season (Collins and George 1997). Pallas et al. (2001) observed a linear increase in yield with increasing crop loads and a curvilinear pattern of decrease in mean fruit weight as the number of fruits per tree increased. Besides yield and fruit size, crop load may also affect fruit firmness and total soluble solids, total acidity and other chemical properties (Watkins et al. 1989; Volz et al. 1993; Johnson 1995; Tough et al. 1998).

As for starfruit (*Averrhoa carambola*), previous studies have shown that yield increases when cultivated under netted structure (Zabedah et al. 1999). Another study conducted on starfruit under the netted structure, showed that plant physiological performance and yield of starfruit were significantly influenced by crop load. It was the objective of this study to determine the effects of crop load on fruit size, exportable yield, fruit physical and chemical properties.

Materials and methods

Starfruit plants were induced to flower by pruning the branches 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 were achieved by thinning fruits especially curved and over clustered fruits. Thus, there were six single tree replications for the three treatments (*Table 1*), giving a total of 18 treatment plants arranged in completely randomized design (CRD). The three crop load treatments are shown in *Table 1*.

Fruit size

All fruits of the experimental trees were classified into sizes. Only good well formed fruits, of the right colour, free of insect and

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. Classification of starfruit by weight for export market by FAMA

Fruit size	Fruit weight (g)
VS	80–100
S	103–136
M	137–170
L	171–210
XL	211–253

disease damage, and free of bruises were sorted into sizes. The rest of the fruits were considered as reject fruits. The good fruits were categorized into sizes according to FAMA standard for export to Europe as shown in *Table 2*. Individual fruits were weighed using a compact scale FEJ-3000D. The number of fruits of the various sizes were counted and recorded. Exposed fruits were rejected because they appeared bleached and lacked luster.

Fruit density

Fruit density was obtained by dividing the fruit weight with the fruit volume. The fruit weight was measured using a compact scale FEJ-3000D. The fruit volume was measured using water displacement method.

Fruit firmness

Fruit firmness was measured on the harvest day. Fruit firmness was measured on fruits of ripening index 3, using a penetrometer fitted with needle probe. The fruits were measured twice on each side and five fruits were used for each sample.

Chemical properties

The fruits of three samples of each fruit type were homogenized in a waring blender. These samples were analysed for total soluble solids (TSS) and ascorbic acid (vitamin C).

Juice sample from the homogenate was measured for TSS using a digital refractometer. Ascorbic acid was based on the reduction of 2, 6-dichlorophenol indophenol by ascorbic acid. Ten grammes of sample was blended with 3% metaphosphoric acid (HPO₃) and made up to 100 ml with HPO₃ then filtered. An aliquot of the HPO₃ extract of the sample was titrated with the standard dye (Ranganna 1977).

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

Fruit size

The fruits were classified into five sizes, namely very small (VS), small (S), medium (M), large (L) and extra large (XL). Fruits exportable to Europe are mainly in the S, M and L sizes. The VS and XL fruits are sold locally and considered as reject.

Number of exportable size fruits

The number of fruits of the various exportable sizes was significantly affected by the crop load treatments ($p < 0.05$). The number of fruits of the S size increased with increase in crop load. At the lowest crop load, there were less than 20 S size fruits/tree, whereas there were more than 160 S size fruits/tree at the highest crop load. Similar trend was observed for the M size fruits. Although the number of L size fruits tend to increase as the crop load increased, and then decreased slightly at the highest crop load, the difference was not significant (Figure 1).

Number of exportable boxes of various sizes

The number of exportable boxes of the various sizes per tree was significantly

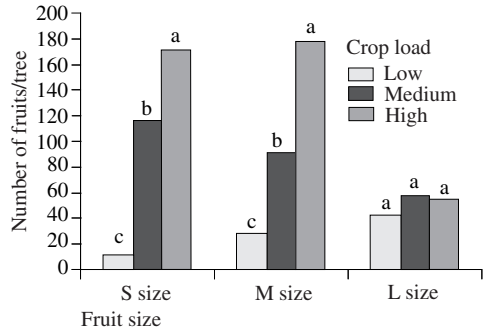


Figure 1. The effect of crop load on number of fruits of various sizes, S, M and L. For each fruit size, values followed by different letters are significant at $p < 0.05$

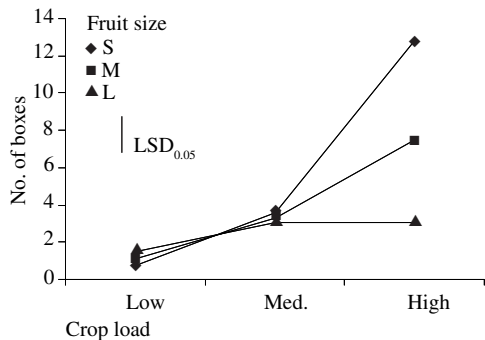


Figure 2. Effect of crop load on number of exportable boxes per tree

affected by the crop load (Figure 2) ($p < 0.05$). The number of S boxes increased from 1 box/tree at the low crop load to 13 boxes/tree at the highest crop load. Similar trend was observed for the number of medium size boxes. However for the L size fruits, although the number of exportable boxes showed a slight increase with increase in crop load, the difference was not significant.

Exportable yield, percentage of export and estimated export

The exportable weight is the total weight of the S, M and L size fruits. The exportable weight increased significantly ($p < 0.05$) with increase in crop load. At the low crop load, exportable yield was around 10 kg of exportable fruits/tree, increased to 56 kg/tree at the high crop load. The same trend of

Table 3. Effect of crop load on exportable yield, percentage of export and estimated yield/ha

Crop load	Exportable yield (kg/tree)	% of fruit export	Estimated export (t/ha)
Low	10c*	51.2b*	3.0c
Medium	27b	69.6a	8.1b
High	56a	75.2a	16.8a

*Means followed by different letters within the same column are significantly different at $p < 0.05$

Table 4. Effects of crop load on number and percentage of reject fruits

Crop load	Fruit number/tree		Percentage/tree	
	VS	XL	VS	XL
Low	3c*	13a*	3c*	15a*
Medium	23b	11a	10b	5b
High	141a	3b	26a	0.6c

*Means followed by different letters within the same column are significantly different at $p < 0.05$

crop load effect was observed on estimated export. About 3 t/ha at the lowest crop load, the estimated export increased to 8 t/ha at the medium crop load and 17 t/ha at the highest crop load.

The percentage of exportable fruits also increased with increase in crop load, around 51% for the lower crop load, reaching about 75% for the highest crop load (Table 3).

Reject fruits

The reject fruits are fruits that are very small (VS) and oversize (XL) fruits. Table 4 shows the effects of crop load treatments on number of VS and XL fruits and their percentage. The number of VS fruits increased significantly ($p < 0.05$) with increase in crop load, reaching 141 fruits/tree/harvest at the highest crop load of 500–600 fruits/tree. A reverse trend was observed for the number of XL fruits/tree with increase in crop load ($p < 0.05$).

Similar trend was observed for the effects of crop load on percentage of VS fruit where the percentage of VS fruit increased with increase in crop load. A

reverse trend was also observed for the percentage of XL fruits/tree with increase in crop load (Table 4). Thus, increase in crop load of starfruit resulted in increase in gross yield and exportable yield with higher yield of the M and S size fruits. Simultaneously, the number and percentage of VS fruits increased and XL fruits decreased with crop load.

Thus as crop load increased, fruit size decreased. This is clearly illustrated by the number of fruits of the various sizes. The reduction in number of big size fruits and increase in small size fruits might be related to the supply of assimilates at various crop loads. The reduction in fruit size of the high crop load may be due to the dramatic increase in demand for carbohydrates, water and nutrients. This result is supported by the work of Bertin (1995), who reported that any treatment that affect the supply of assimilates such as fruit thinning, with or without any effect on cell number should also affect fruit size. Increase in exportable yield with increase in crop load was also observed by Palmer et al. (1997), Dokoozlian et al. (1998) and Pallas et al. (2001).

Balasubramaniam and Agnew (1996) observed a good relationship between crop load and fruit size of cherry. Reduction in crop load of cherry resulted in 26% increase in individual fruit weight and a 54% reduction in total yield. Since consumer market prefers large cherries from 8 grammes or more fruit weight, crop load needs to be managed to achieve the desired fruit size. As far as starfruit is concerned, increasing crop load to 500–600 fruits per tree resulted in higher yield of M and S size fruits, which are preferred by the European market, thus resulted in increase in exportable yield.

Fruit physical properties

Fruit density and firmness were not significantly influenced by the crop load. All crop loads showed fruit density of 1.05 g/cm³ and fruit firmness of 1.2. This

Table 5. Effects of crop load on fruit chemical properties

Crop load	Vitamin C (mg/100 g)	TSS (%)
CL1	17.62a	12.76a
CL2	17.01a	11.46a
CL3	16.31a	11.44a

Means followed by the same letters within the same column are not significantly different at $p < 0.05$

may indicate the crop load did not influence the intracellular spaces of starfruit. However, other workers working on apples observed that light cropping trees of apples are higher in firmness (Watkins et al. 1989; Johnson 1995; Tough et al. 1998).

Fruit chemical properties

Both the ascorbic acid (vitamin C) and total soluble solids (TSS) were not significantly affected by the crop loads (Table 5). Many workers (Volz et al. 1993; Genard et al. 1998; Tough et al. 1998) observed higher TSS in fruit with lower crop load. Similar to this study, Opara and Tadesse (2000) found no consistent effect of crop load on TSS of 'Pascific Rose' apple. The non-significant result of TSS by crop loads in starfruit may be due to the inherent quality of starfruit cultivar B10 which has low TSS value, 10–11 at maturity index 4 (Abd. Rahman and Johari 1992). This is also in agreement with Marler et al. (1994) who suggested that TSS of starfruit is genetically determined.

The fruit ascorbic acid concentration was not influenced by the crop load probably due to sufficient supply of nutrients received by plants of the various crop loads (Zabedah 2007). Similar observation was made by Stopar et al. (2002) on Jonagold apples. It has been reported that high nitrogen application resulted in low ascorbic acid while high potassium fertilizer can increase the ascorbic concentration of fruits (Nagy 1980). Thus in crop manipulation, it is important to ensure that the plant is provided with sufficient nutrients so that the fruit chemical properties such as ascorbic

acid concentration is not reduced with increase in crop load.

Conclusion

Increase in crop load resulted in significant increase in exportable yield. The percentage of exportable yield increased from 40–50% at the lower crop load to 75% for the higher crop load. The number of very small (VS) fruits (reject fruit) increased significantly with increase in crop load, reaching 141 fruits/tree/harvest at the highest crop load. Fruit density and fruit firmness were not influenced by the crop load. The ascorbic acid and TSS were not affected by the crop loads. Thus, increase in crop load did not have negative influence on fruit chemical and physical properties. Since increase in crop load resulted in higher number of exportable size fruits (M and S), which are preferred by the European market, it is recommended that under netted structure, fruit load can be maintained up to 500–600 fruits/tree/season as fruit qualities are not affected.

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Abstrak

Kesan kelembatan buah terhadap hasil yang boleh dieksport dan saiz buah belimbing besi di bawah struktur pelindung telah dikaji di ladang belimbing MARDI, Serdang, Selangor. Bilangan buah saiz kecil (S) dan sederhana (M) bertambah apabila kelembatan buah bertambah. Peratus buah yang boleh dieksport bertambah daripada 50% pada pokok yang kurang lebat kepada 75% pada pokok yang sangat lebat ($p < 0.05$). Bilangan buah saiz S dan M yang boleh dieksport bertambah daripada 1 kotak/pokok pada pokok yang kurang lebat kepada 13 kotak/pokok saiz S dan 7–8 kotak/pokok saiz M pada pokok yang sangat lebat ($p < 0.05$). Bilangan buah yang amat kecil (VS) dan buah terlalu besar (XL) juga dipengaruhi oleh kelembatan buah. Bilangan buah VS mencapai 141 biji/pokok dan berkurangan pada pokok yang kurang lebat. Keadaan di sebaliknya pula berlaku dengan bilangan buah XL sepokok. Ketumpatan buah dan kekerasan buah tidak dipengaruhi oleh kelembatan buah. Buah pada pokok yang kurang lebat mempunyai hujung kepek yang lebih tebal berbanding dengan buah dari pokok yang lebat ($p < 0.05$). Buah pada pokok yang kurang lebat juga mempunyai tapak kepek yang lebih lebar berbanding dengan kelembatan tinggi ($p < 0.05$). Kandungan vitamin C dan kepekatan pepejal terlarut tidak dipengaruhi oleh kelembatan buah.