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Full Length Article

Application of Girdling for Improved Fruit Retention, Yield and Fruit Quality in *Syzygium samarangense* under Field Conditions

MOHAMMAD MONERUZZAMAN KHANDAKER[1], ABM SHARIF HOSSAIN, NORMANIZA OSMAN AND AMRU NASRULHAQ BOYCE
Institute of Biological Sciences, Faculty of Science, University of Malaya, 50603, Kuala Lumpur, Malaysia
[1]Corresponding author's e-mail: kmoneruzzaman@yahoo.com

ABSTRACT

The study was undertaken to investigate the effects of different girdling techniques on the yield and quality of wax jambu fruits (*Syzygium samarangense*). Physiological and biochemical parameters were monitored at one week intervals during the three successive growth period from January, 2009 to May, 2010, using I-25%, C, V shaped, I-50% and 100% girdling. Girdling was applied three weeks before flowering every season. It was observed that the C-shaped girdling technique significantly enhanced the inflorescence development and produced the best results with regard to the fruit retention, fruit size, leaf chlorophyll and drymatter in comparison to the control and the other girdling techniques employed. Furthermore, C-shaped girdling enhanced faster fruit growth producing the best final fruit length and diameter, in addition to significantly increased number of fruits and mean fruit weight. It was also observed that I-50% girdling increased the L\D ration of fruit. I-shaped girdling increased the photosynthetic yield and dry matter content in the fruits compared to the control. With regard to fruit quality, the application of C-shape girdling increased total sugars, total phenolics and anthocyanins content in the fruits by 87, 28 and 138%, respectively compared to the control treatment. V-shape girdling increased the total flavonoids 150% more than control fruits. Girdling practices increased the antioxidant activity in the fruits. From this study, it can be concluded that girdling applied before flowering enhanced inflorescence development, increased yield and quality of wax jambu fruits under field conditions. © 2011 Friends Science Publishers

Key Words: *Syzygium samarangense*; Girdling; Fruit retention; Fruit yield; Fruit quality
Abbreviations: L/D ratio, Length diameter ratio; MARDI, Malaysian Agricultural Research and Development institute; CE, Catechin equivalent; GAE, Gallic acid equivalent; TEAC, Trolox equivalent antioxidant capacity; DPPH, 2, 2-diphenyl-1-picryhydrazyl.

INTRODUCTION

The *Syzygium samarangense* commonly known as wax jambu is a tropical fruit tree with presumably originated in Malaysia and other south-east Asian countries. Wax jambu is a non-climacteric in nature which belongs to the family Myrtaceae (Morton, 1987). Currently in Malaysia it is cultivated mainly as smallholdings ranging from 1 to 5 ha with its total hectarage estimated at about 2000 ha in 2005 (Zen-hong *et al.*, 2006). In Malaysia, the ripe pink fruits of wax apple are bell-shaped, sweet and can be eaten fresh or cooked, for sauces, jams, jellies desserts, wines, liquors and vinegars. Ninety percent or more of the fruit is edible. The fruits can be used for several inflammatory conditions, including sore throat, high blood pressure, ringworm, and as an antimicrobial, antiscorbutic, carminative, diuretic, and astringent (Rivera & Obon, 1995).

Malaysian climate is suitable for the wax jambu production. Fruit can be harvest all year-round. There is a great scope to develop wax jambu industry in Malaysia and other tropical countries. Severe fruit drop and low quality impair wax jambu production, resulting in lower market prices. Girdling considered an important practice responsible for improving fruit setting, yield as well as physical and chemical properties of fruits. Thus, the research can assist to develop wax jambu as well as tropical fruit industry in Malaysia.

Girdling has been, and is still, worldwide horticultural practice used to manipulate tree growth and development. Girdling consists of removal of a strip of bark from the trunk or major limbs of a fruit tree, thereby blocking the downward translocation of photosynthates and metabolites through the phloem. The best-known effects of girdling are presumably brought about by accumulation of assimilates above the girdle (Chun *et al.*, 2003). As a results of girdling leaf N content, C/N ratio and carbohydrate were improved. Therefore, flowering and fruit set were increased (Shao *et al.*, 1998). Rivas *et al.* (2007) reported that girdling few weeks before flowering reduced fruitlet abscission, increased leaf chlorophyll content and chlorophyll

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fluorescence. Furthermore, it increased quantum yield and carbohydrate concentration in various flowering and vegetative shoots in citrus. Mostafa and Saleh (2006) reported that girdling plus potassium spray increased the total number of fruits and yield weight per tree. It has been well documented that the ringing of trees can bring about an increase in the size and sugar content of fruits and cause them to mature a few days to a week earlier (Onguso *et al.,* 2004; Hossain *et al.,* 2007; Hossain & Boyce, 2009).

Girdling increased total phenolic content and L-phenylalanine ammonia lyase activity in peach fruit (Kubota *et al.,* 1993). Casanova *et al.* (2009) reported that scoring (one type of girdling) significantly increased the total sugar content in grape. It has been reported that girdling increased the levels of total and individual anthocyanins in the berry skin of crimson seedless grapes (Harsimranjit *et al.,* 2008). Rivas *et al.* (2008) reported that girdling treatment increased the leaf soluble sugar content and all antioxidant enzyme activities. They also found close relation between leaf soluble sugar and antioxidant enzyme.

The aim of the present study was to check the effects of different types of girdling on inflorescence development, fruit retention, yield and quality of wax jambu under field conditions. The relationships between total soluble sugars content and phytochemical properties in the ripening fruits, provided information about the effects of girdling on nutritional effects.

MATERIALS AND METHODS

Plant material and experimental site: Experiments were conducted in 2008, 2009 and 2010 on the branches of wax jambu tree *(Syzygium samarangense)*, in two orchards one is MARDI, jalan kebun, Klang located at an elevation of 147 ft from sea level, where the trees planted in a 14.5 ft × 14.5 ft in hexagonal pattern and another a smallholder commercial orchard consisting of 12 year old *Syzygium samarangense* trees, near Banting town, south of the capital Kuala Lumpur, Malaysia. The experiments were conducted over a period from October, 2008 to January, 2010.

The trees were irrigated every seven days with fertilizers and insecticides applied according to the recommendations of the State Agricultural Department. Four trees were selected for the study and all the six different treatments were represented once in each tree. Treatment was randomly allocated to each of six uniform branches of each tree. The experiments were arranged in a completely randomized design (CRD) with four replications.

Girdling: Different girdling techniques namely, I-25% shaped, I-50% stress, 100% stress, V-shaped and C-shaped girdling were applied three weeks before flowering. To setting I-25%, I-50% and 100% girdling on treatment branches 75%, 50% and 100% phloem were removed respectively. C and V-shaped girdling techniques were applied by keeping the C and V-shape phloem connectors on the treatment branches (Fig. 1). Girdling was performed using a girdling knife, which simultaneously cuts and removes the bark strips. The width of the girdle was 5 mm. In all the cases the cut reached the cambium and was left bare without injury to the inner layer. Partial ringing (I, C & V) was done by removing a partial ring 4 cm long and leaving a connecting strip 2 mm of I, C and V shape on the main stem. In the case of complete bark girdling, the bark was removed in ring fashion around the stem, without any phloem connection left. All the girdling was carried out 3 weeks before flowering.

Measurement of physiological and biochemical parameter: Inflorescence development of the tagged branches was monitored carefully. Observations were made at three days interval. For the determination of fruit retention (%) from the tagged branches on the experimental tree, the number of fruit at 7 days after anthesis and number of fruit before harvesting percentage fruit retention was calculated. Fruit length and width was also determined with the help of Vernier caliper. Total number of fruits and fruit weight were recorded by counting and weighing the total number of fruits per treatment at the time of harvesting. The chlorophyll and carotene content of leaf and fruit were determined by methods described in Hendry and Price (1993). Chlorophyll fluorescence was measured by Hansatech Plant Efficiency Analyzer. It was represented by Fo, Fm, Fv and Fv/Fm, Where, Fo = Lower fluorescence, Fm = Higher fluorescence, Fv = Relative variable fluorescence (Fm-Fo). Fv/Fm =Photosynthetic yield or quantum yield. Temperature = 28°C. Time range = 10 μs^{-3}.

Total soluble sugars were the determined according to phenol-sulphuric method of Dubois (1956). The total phenolic content of wax jambu fruit was determined by using the Folin-Ciocalteu assay of Singleton and Rossi (1965). Total flavonoid content was determind by the aluminum chloride colorimetric assay (Zhishen *et al.,* 1999). Antioxidant capacity was determined via 2, 2-diphenyl-1-picryhydrazyl (DPPH) assay as described by Tadolini *et al.* (2000) and the TEAC assay according to Rice-Evans *et al.* (1997). Total anthocyanin contents of the hydrophilic extracts were measured by the pH-differential method described by Rodriguez-Saona *et al.* (1999).

Statistical analysis: The experimental design was a completely random design with four replications. The data obtained were analyzed using MSTAT statistical software. One way ANOVA was applied to evaluate the significant difference in the parameters studied in the different treatments. Duncan's multiple range test (DMRT) was calculated, following significant F-test (P=0.05).

RESULTS

Inflorescence development and fruit retention: Different types of girdling significantly reduced the time needed for inflorescence emergence and the time of flowering (Table I). Results showed that C-shape, 100% and V-shape girdling produced the flowering with a day of 9, 11 and 12 followed by 50% and I-shape girdling with a day of 13 and 15. Whilst, it took 21days to flowering in control treatment (Table I). Different girdling treatments increased the C/N ratio in the treated branch, it might be enhanced the inflorescence development. Girdling treatment had a significant effect on fruit retention capacity of the plant. Data in Table I shows that the fruit retention was almost 1.35 fold in C-shape girdling treatment compared to control. All the girdling treatments posted higher fruit retention values compared to than the control, which was about 48% fruit retention per branch.

Fruit size (length & diameter) and L/D ratio: As can be seen from the Table I fruit size (length & diameter) was significantly influenced by different girdling treatments. C-shape girdled branches produced the highest fruit length and diameter to about 6.9 and 4.8 cm. This was followed by V-shape and the other treatments. Control branches produced worst fruit at about length and diameter to about 5.43 and 3.93 cm. Length and diameter ratio of fruits also affected by different types of girdling. Results showed that highest L/D ratio was found in 50% girdling followed by I-shape and other treatments. Control branches produced the lowest L/D value although their difference was not statistically significant.

Drymatter (DM) and mean fruit weight (g): From the results, it can be seen that fruits and leaf drymatter was significantly affected by different types of girdling. C-shape girdling posted the highest amount of fruits and leaf dry matter with a value of 3.72 and 1.92 g. This was followed by V-shape and other treatments, whilst control treatment produced the lowest value in case of fruit and leaf dry matter. The data on fruit weight showed significant results for each time of analysis. In first season, highest fruit weight (51 g) was recorded in C-shape stress followed by 1-shape, 50% and 100% stress, respectively with a weight of 49, 47 and 46g, whereas, lowest fruit weight (35 g) was found in case of control (Fig. 2). During the 2nd season analysis, highest mean fruit weight (50 g) was recorded in C-shape stress followed by V-shape, I-shape and 50% stress respectively, whereas, lowest (34 g) fruit weight was found in case of control. Similar observations were also recorded in 3rd season in case of mean fruit weight. From the Fig. 2, it is clear that different girdling treatment had a significant effect on mean fruit weight.

Number of fruits: In this study, different girdling techniques were employed to observe their effects on number of fruits. From the results of first season (2008), it was found that there was a significant difference between the girdling techniques and the control (Fig. 3). Similarly in the second (2009) and third growing seasons (2010) fruits of the different girdled branches produced significantly more total number of fruits (Fig. 3). In the first season the highest number of fruits (11) was recorded in C-shaped girdling followed by V-shape, 50% and I-shape girdling, whereas less number of fruits (4) was recorded in control plants (Fig.

Fig. 1: Photograph showing different type of girdling used in the study

Fig. 2: Mean fruit weight as affected by different girdling techniques. Different letters in the column represent significant difference at P < 0.05 level by DMRT

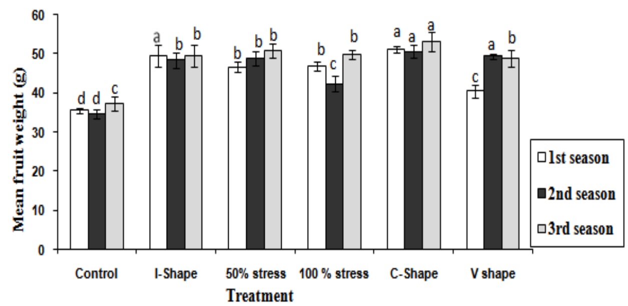
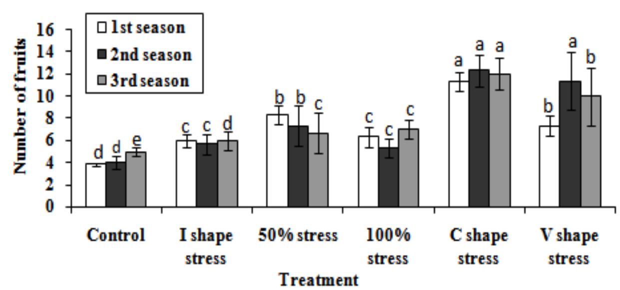


Fig. 3: Total number of fruits as affected by different types of gridling techniques



3). During the 2nd season analysis, highest number of fruits (12) was recorded in C-shape stress followed by V-shape, I-shape and 50% stress respectively, whereas, lowest (4) fruit weight was found in case of control. In the third season again, the results showed the positive effects of the girdling treatments.

Leaf chlorophyll and chlorophyll fluorescence and quantum yield: In this study the chlorophyll *a* chlorophyll *b* and total chlorophyll content was determined using the methods described in Hendry and Price (1993). From this study, it could be seen that different girdling treatment had a significant effect on chlorophyll a, chlorophyll *b* and total chlorophyll in the leaves. As shown in Table II C-shape girdled branches produced the highest amount of

Fig. 4: Chlorophyll fluorescence intensity as affected by different types of girdling. *Fo*=lower fluorescence, *Fm*= higher fluorescence and *Fv*=Relative variable fluorescence

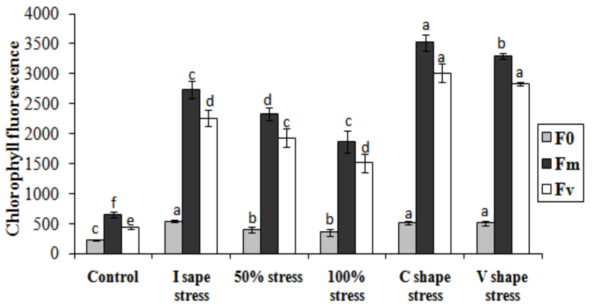


Fig. 5: Photosynthetic yield (Fv/Fm) as affected by different treatments of girdling

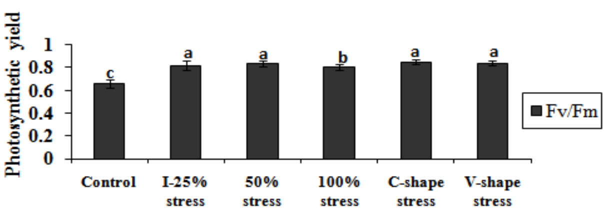
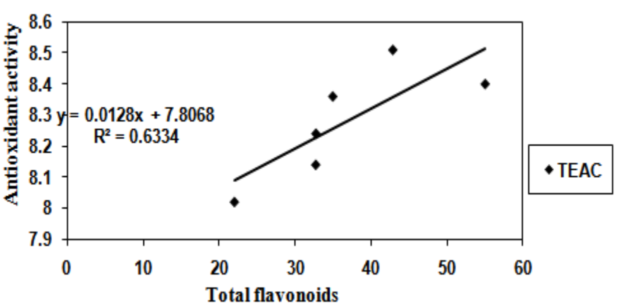


Fig. 6: Correlation between total flavonoids and antioxidant activity via TEAC methods in the girdled fruits



chlorophyll a (4.51 mg/kg), chlorophyll b (3.11 mg/kg) and total chlorophyll (7.62 mg/kg) followed by V-shape, 50% stress and I-shape stress, whereas, control treatment produced the lowest amount of chlorophyll content. From the results it was also found that chlorophyll content started to decrease with the increase of removal of phloem surface area. Leaves of 100% girdled branches produced the lowest amount of chlorophyll among the different treatments. Different girdling treatments produced the significant effects on chlorophyll fluorescence in the leaves (Fig. 4). Chlorophyll fluorescence intensity was found fluctuated trend in case of all treatments. The highest fluorescence (Fm) was observed in C-shaped branch followed by V-shape, I-shape and 50% stress with a value of 3520, 3297, 2733 and 2332, whilst leaves of control branch produced the lowest (643) Fm value. Lower fluorescence (F^o) was also highest in C-shaped stress followed by V-shape, I-shape and 50% stress with a value of 512,505, 473 and 398, whereas control was the lowest 217. Variable fluorescence (Fv) was highest in C-shaped branch branches followed by V-shape, I-shape and 50% stress, whereas control performed least fluorescence (Fig. 3). Different girdling treatments also produced the significant effects on the quantum yield or photosynthetic yield. From Fig. 5, it could be seen that optimum quantum yield [(Photosynthetic yield (Fv/Fm)] was highest in C-shape girdling treatment followed by V-shape, 50% stress and I-shape with a value of 0.85, 0.84, 0.84 and 0.80, while control produced the lowest (0.66) photosynthetic yield.

Total sugars content: Total sugars content of fruit juice was found to be statistically significant between the different treatments and control treatment. From the results of 1st season (2008), it can be seen that different girdling treatments produced the significant difference between the treatments and control. Similarly in the 2nd season (2009) fruits of different girdled branches produced significantly more total sugar (g/100 g) in the fruits (Table III). From the results, it was observed that the highest (6.8 g/100 g) total sugar was recorded in C-shape stress fruits followed by V-shape, I-shaped, 50% and 100 % stress with a sugar content (g/100 g) of 6.57, 6.18, 4.75 and 4.64 g/100 g, respectively (Table III), while the lowest total sugar (3.63 g/100 g) was recorded in untreated fruits. In the third season (2010) again, the results showed the positive effects of the girdling treatment on the total sugar content in the fruits.

Total phenolics and flavonoids in fruit: The application of different types of girdling had a significant effect on the total phenolic content of wax jambu fruits (Table III). Fruits from C-shaped girdled branches exhibited the highest amount in the region of 635 mg/100 g of phenols followed by 100%, 50%, V and I-shaped branch with phenols content of 626, 585, 508 and 455 mg/100g, respectively. Control fruits exhibited the lowest phenol content 396 mg/100 g. From the results shown in Table III, it was observed that fruits of different girdling treatments produced higher flavonoid content than the control treatment and their difference was statistically significant. As can be seen from the Table III, branches with V-shape girdles produced fruits with the highest flavonoids content (55 mg CE/100 g) followed by C-shape, I-shape and 50% stress treatments which recorded values of 42, 34 and 32 mg CE/100 g respectively, while the control fruits produced the lowest (22 mg CE/100 g) flavonoid content.

Antioxidant activity, anthocyanins content and Correlation between antioxidant and total flavonoids: Antioxidant activity via DPPH assay was not found statistically significant between the treatments and control fruit. All the girdling treated fruits exhibited a little bit higher antioxidant activity in the fruits compare to control fruits, which was not statistically significant. Among the different girdle, C and V-shaped girdle treated fruit showed

Table I: Effects of different types of girdling on number of buds, bud dropping, fruit setting, fruit dropping and yield of wax jambu

Treatments	Inflorescence develop (d)	Fruit retention (%)	Fruit length (cm)	Fruit diam. (cm)	L/D ratio	Fruit DM (g)	Leaf DM (g)
Control	21±0.88^{a}	48±1.73^{e}	5.43± 0.50^{f}	3.93± 0.26^{f}	1.36 ±0.01	2.81± 0.13^{f}	1.22±0.03^{e}
I-S. stress	15±1.45^{b}	59±2.95^{cd}	6.49± 0.32^{c}	4.50± 0.06^{d}	1.44 ±0.02	3.76±0.15^{a}	1.88±0.05^{ab}
50% stress	13±0.89b^{c}	61 ±1.52^{bc}	6.46± 0.68^{d}	4.43 ± 0.23^{de}	1.45± 0.01	3.16±0.21^{d}	1.68±0.26^{bc}
100% stress	11±0.96^{cd}	58±1.73^{d}	6.40± 0.45^{de}	4.60±0.60^{bc}	1.40± 0.01	3.03±0.33^{e}	1.51±0.23^{d}
C-S. stress	09± 1.75^{e}	65±2.64^{a}	6.90 ± 0.55^{a}	4.83±0.25^{a}	1.43 ±0.02	3.72±0.57^{ab}	1.92±0.15^{a}
V-S. stress	12±1.70^{c}	64±1.73^{ab}	6.63± 0.34^{b}	4.66±0.27^{b}	1.42±0.02	3.63±0.20^{c}	1.74±0.12^{b}
Significance	**	*	**	**	ns	**	**

Table II: Leaf chlorophyll content as affected by different types of Girdling techniques (n=6)

Treatment	Chlorophyll *a* (mg/kg)	Chlorophyll *b* (mg/kg)	Total chlorophylls (mg/kg)
Control	2.99±0.36^{f}	2.02±0.18^{e}	5.01±0.54^{f}
I-S. stress	3.28±0.59^{d}	2.18±0.32^{d}	5.46±0.91^{d}
50% stress	3.53±0.48^{c}	2.63±0.18^{bc}	6.16±0.66^{c}
100% stress	3.19±0.34^{de}	1.91±0.37^{f}	5.10±0.71^{e}
C-S. stress	4.51±0.17^{a}	3.11±0.42^{a}	7.62±0.59^{a}
V-S. stress	4.09±0.46^{b}	2.71±0.34^{b}	6.80±0.80^{b}
Significance	**	*	**

Table III: Effects of different types of girdling on Total sugar, total phenol, total flavonoids, AEAC and DPPH concentrations of wax jambu

Treatments	Total sugar (g/100 g pulp)			Total phenols	Total flavonoids	DPPH (mg/100 g)	Anthocyanins
	1st season	2nd season	3rd season	(mg GAE/100 g)	(mg CE/100 g)		(mg/g)
Control	3.14±0.58	3.63± 0.69f	3.95 ±0.47	396± 86.51	22.00 ± 3.76f	13.70± 0.15	2.03±0.05f
I-S. stress	3.77±0.53	6.18±0.40bc	5.44±0.34	455± 112.9	34.95± 4.17c	14.25± 0.14	4.00±0.06cd
50% stress	4.85±0.55	4.75± 0.46de	4.45±0.55	585± 91.09	32.73± 3.70de	14.27± 0.16	4.32 ±0.03bc
100% stress	4.76±0.50	4.64±0.54cd	4.64±0.53	626± 74.47	32.70± 7.21b	14.32±0.19	3.87 ±0.11de
C-S. stress	5.57± 0.47	6.8 ±0.31a	6.57±0.59	635 ± 109.1	42.85± 3.21cd	14.40 ±0.13	4.84±0.02a
V-S. stress	5.07± 0.57	6.57 ±0.09b	6.41±0.34	508 ± 150.3	55.00± 7.70a	14.42 ±0.11	4.56±0.08ab
Significance	**	**	**	*	**	ns	**

Mean separation in line by Duncan's multiple range test at $P<0.05$, ns, non-significant, *Significant at 0.05 levels, ** Significant at 0.01 levels

higher antioxidant activity compare to other girdle and control treatment. As shown in Table III, different types of girdling had a significant effect on the anthocyanins content in wax *jambu* fruits. The highest (4.84 mg/g) amount of anthocyanins was observed in C-shape girdled fruit followed by V-shape, 50% and I shaped girdling with a value of 4.56, 4.32 and 4.00 mg/g, whereas untreated control fruit showed the lowest amount of anthocyanins content (2.03 mg/g). A high correlation between the total flavonoids content and TEAC measurements was observed (R^2=0.633) in fruits of C-shaped girdle (Fig. 6).

DISCUSSION

The immediate effect of a girdle is to interrupt the movement through the phloem of photosynthates produced by leaves. This increases foliar carbohydrates (sugars & starch) and plant hormones in above parts of the girdle which enhances the flowering (Roper & Williams, 1989). Our results showed that girdling treatments significantly reduced the flowering time as well as enhanced inflorescence development. Similar observations have been reported by Arakawa *et al.* (1997) in apple, who reported that girdling enhanced the inflorescence development. Girdling treatment increased the accumulation of carbohydrate content in the upper part of girdle (Chun *et al.*, 2003). The increase in carbohydrate level in the leaves a well correlated with the fruit retention. Different girdling treatments especially C and V-shapes increased the fruit retention capacity from other treatments and control (Table I). The increase in fruit retention with girdling application may be ascribed to increased level of carbohydrates, especially during initial 4-6 weeks of heavy fruitlet abscission. Our results are supported by the findings of Shao *et al.* (1998). They reported that girdling treatment increased the C/N ratio and carbohydrate content thus reduced the fruitlet abscission and increased the fruit retention of citrus. Girdling has been practiced to increase productivity in many fruit trees (McNeil, 2001). The increase in fruit size demonstrated here in response to girdling application at the three weeks before flowering (Table I) may indicate their ability to stimulate carbohydrate translocation to the fruit in combination with their effect on increasing cell wall elasticity. Thus, our results could be in agreement with the finding of Mustafa and Saleh (2006), who reported that girdling alone or with potassium spray increase the fruit size and fruit weight in Balady mandarin orange. The girdle branch increased the leaf and fruit drymatter than the nongirdle branch (Famiani *et al.,* 2000). Consequently, we can conclude that girdling treatment increased the leaf and fruit drymatter of wax jambu (Table I). Chen *et al.* (2009) reported similar results in Oolong Tea. They stated that girdling significantly increased the dry matter content in the leaf as well as increased the quality of leaf.

Fruit weight is an important quality parameter of fruit production. Bark ringing or girdling significantly increased the fruit weight as well as yield (Hossain *et al.,* 2007). By contrast, in the current study, different girdling treatment significantly increased the fruit weight (Fig.2). Our results are supported by the findings of Juan *et al.* (2009). They reported that scoring one type of girdling significantly increased the fruit weight in persimmon. Girdling can improve carbohydrate availability to fruits and as a consequent lead to an increase in fruit-set and yield as well as number of fruits (Goren *et al.,* 2003; Rivas *et al.,* 2004). In this context, all the girdled branches produced the higher number of fruits than the untreated control fruit (Fig. 3). Thus, our results are could be in agreement with the findings of Casanova *et al*. (2009), who observed that scoring (girdling) had no negative effect on the number of harvested bunches per vine the year following the scoring year, both in ‘Emperatriz’ and ‘Aledo’ cultivars.

Girdling treatments significantly increased both total chlorophyll and chlorophyll (a) compared with the untreated trees (Mostfa & Saleh, 2006). Accordingly, in our study, girdling increased the leaf chlorophyll *a*, *b* and *a*+*b* (Table II). In addition, several authors have proposed that total leaf carbohydrate content and starch increased as a result of girdling (Rivas *et al.,* 2008). It may be due to the accumulation of chlorophyll content and increased photosynthesis in the girdled branch. Chlorophyll fluorescence has become one of the most powerful and widely used techniques available to plant physiologist and ecophysiologist. Chlorophyll fluorescence gives information about the state of photosystem II (PS-II). In this study, different types of girdling shown a significant difference in case of chlorophyll fluorescence and quantum yield (Fig. 4 & Fig. 5). Rivas *et al.* (2008) reported similar results in citrus cultivars. They reported that girdling did not affect the chlorophyll fluorescence in mature leaf but in case of young leaves of chlorophyll fluorescence start to increase from 30 DAG. They also reported that girdling increased the quantum yield of PS-II.

Verreynne *et al.* (2001) reported that girdling enhanced fruit color, total soluble solids and total sugar content in Marisol’ Clementine’s. Fruits from the girdle branch yielded the higher amount total sugars which may be due to carbohydrate availability and starch content high in upper part of girdle (Table III). These results are in agreement with the findings of Kazutoshi *et al.* (2009), who reported that sugar content increased in Japanese persimmon, in phloem ringed plants compared to the control. Phenolic compounds in fruits are important, because they can exhibit antioxidant properties. Girdling as a treatments had a significant effect on total phenolic content in wax jambu fruit (Table III). Our findings agree with those of Kubota *et al.* (2001). They reported that girdling significantly increased the PAL enzyme activity and total phenolic content in the peach fruits. Flavonoids have diverse beneficial biochemical and antioxidant effects (Donald & Cristobal, 2000) and it impart color and taste to flowers and fruits (Pietta, 2000). In our study, it has been seen that girdling treatments increased the total flavonoids content in the fruit (Table III). These findings are supported by the results of Harsimranjit *et al*. (2008), who observed that girdling increased the flavanols content in the grape. In this context, we also analysed the effects of girdling on antioxidant activity of the fruits.

Results showed that girdling enhanced the antioxidant activity of fruits (Rivas *et al.* 2008). Anthocyanin pigments are responsible for the red, purple and blue colours of many fruits and also they have possible health benefits as dietary antioxidants (Ronald, 2001). Girdling enhanced color development, ripening and also had positive effects on anthocyanin accumulation in the fruits (Downey *et al.,* 2006). Consequently, we also observed similar effects of girdling on anthocyanin accumulations in the wax jambu fruits (Table III). This variation in the girdling effect on the accumulation of anthocyanins in the berry skin, may be girdling stimulated the activity of F 30, 50-hydroxylase enzyme thereby producing higher levels of trisub-stituted anthocyanins in the berry skin compared to control. Perhaps, girdling of clone 314 enhanced the anthocyanin accumulation in the berry skin by stimulating the supply of photosynthates to the grape berries. Our results also showed that flavonoid with antioxidant activity had a positive correlation in the girdle fruits. These findings are in agreement with the results of Pourmorad *et al.* (2006).

CONCLUSION

Different types of girdling particularly C and V-shaped can increase yield and improve nutritional status of the wax jambu fruit. Treatment with C-shaped girdling improved the inflorescence development, chlorophyll fluorescence and fruit retention and increased number of fruits, mean fruit weight, dry matter and chlorophyll content and total sugars, total phenol and anthocyanin content in the fruits, whilst V-shape girdling was promising for total flavonoids and antioxidant capacity in the fruits. Treatment with I-shape girdling also increased the fruit L/D ratio, photosynthetic yield, peel color, anthocyanins and carotene content. Flavonoid had a positive correlation in the girdle fruits. Thus, C and V-shaped girdling are promising for enhancing the fruit retention, yield and improving the quality of wax apple fruits under field conditions.

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