Residual Effect of Partial Girdling after Three Years on Quality of Satsuma Mandarin Fruit

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ABSTRACT

An experiment was carried out to see the residual effect of partial girdling on fruit quality and bark recovery of Satsuma mandarin three years after the date of girdling operation. In 2003, fruit trees located in the university farm of Ehime University received the girdling treatment of 10cm and 20cm width along with ungirdled branch as control. After three years, the bark recovery was found to be significantly higher in the branches that received girdling of 10cm width than 20cm girdling treatment. The fruit size, total soluble solid content and the titratable acidity were not significantly different among the three treatments. However, the largest fruit (98.4±3.52 g) was obtained from the ungirdled branch while the highest brix (10.5 ± 0.25 %) was recorded in the fruits harvested from the 10cm girdled branches.

Key Words: Acidity, brix, girdling, Satsuma mandarin

INTRODUCTION

Satsuma mandarin (*Citrus unshiu* Marc.) is the leading seedless citrus species in Japan owing to its excellent fruit quality and easiness to remove the peel. However, citrus production in Japan has been declining since 1970 due to competition both by citrus exported from other countries and other fruits like apples, bananas, melons and strawberries. In addition, citrus fruits face competition from industrial/processed products like candy, soft drinks and ice creams, which are more preferred by younger people (Iwagaki, 1995). Therefore, Japanese citrus growers are expected to produce high quality Satsuma mandarin in order to achieve handsome profits (Morinaga *et al.*, 2005). In general, consumers prefer fruits of medium to large size (Wright, 2000; Harty and Anderson, 1997) containing 10-14% sugars and about 1-0.8% titratable acid (Morinaga *et al.*, 2005; Harty and Anderson, 1997). The qualities including TSS content and size of fruits at harvesting are of considerable importance in commercial cultivation since these aspects influence the marketability of fruit.

Improvement in quality of fruit like increase in sugar content in a fruit can be achieved either by decreasing water or increasing carbohydrate availability to fruit along with increase in fruit sink strength. It has been observed that water stress during ripening concentrates fruit sugar resulting in fruits with higher soluble solids content (Iwagaki, 1997). Candido *et al.* (2000) in their experiment on effect of irrigation regime on yield and quality of processing tomato, found that soluble solids were the highest in un-irrigated fruits with 9.2 % Brix followed by fruits where supplementary irrigation was carried out when soil water potential dropped below –1.5 MPa with 7.20 Brix while fields where restoration of 50% and 100% maximum crop evapo-transpiration had 6.4 and 4.60 Brix respectively. Kriedemann and Ian (2003) reported that Brix in over watered 'Okitsu' Satsuma mandarins were the lowest (7.7 %) while water stressed trees produced fruits with the highest Brix (13.2 %), the fruit size was however reduced with water stress.

Carbohydrate partitioning to the fruit is considered as one of the principal factors influencing the fruit growth (Wright, 2000). It is commonly accepted that the availability

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of carbohydrates to any particular fruit is dependent upon the presence of carbohydrate source, i.e. leaves and the number of competitive sinks such as other fruit, rapidly growing shoots and roots. Elimination of competition for the carbohydrate to other parts than the growing fruits is one of the primary methods for improving the fruit quality. Girdling has been tried in several fruit species to improve fruit quality with the assumption that with the removal of a ring of a bark from a trunk or major limbs of a fruit tree, the downward transport of photosynthates and metabolites through the phloem to the roots is blocked resulting in more carbohydrates being available for the fruits and young leaves /shoots (Wright, 2000; Li and Goldschmidt, 2003; Onguso *et al.*, 2005). The size of the girdled portion vary from a single cut without removing a bark to larger sizes that involves removal of a strip of bark of up to 20cm or more. The technique involves temporary disruption of the conductive vessels, the phloem that carry carbohydrates to the roots. It has also been stated that this practice intensifies the moisture stress in the plant (Goell and Cohen, 1981).

In their experiments, Onguso *et al.* (2004), Poerwanto and Irdiastuti (2005), Mataa *et al.* (1997) and Wallerstein *et al.* (1974) using peach, rambutan, 'Ponkan' mandarin and sour orange respectively, observed that girdling increased carbohydrates above the girdled portion and reduced it below the girdle (Poerwanto and Irdiastuti, 2005; Onguso *et al.*, 2005). As a consequence, this will benefit the sinks above the girdle, i.e. the fruits and the shoots.

In 'on' trees, Li and Goldschmidt (2003) observed that there was no increase in total non structural carbohydrates in leaves of girdled trees and slight increase in barks above the girdle while in 'off' trees the concentration of starch in leaves was 3 times than in control and bark twice that of control. This indicates that in 'on' year the fruits use the photosynthates that increase above the girdle. Williams and Ayars (2005) observed that girdling Thompson seedless grapevines decreased water use approximately 15% until the girdle healed. This indicates that girdling may also affect water availability to the fruit.

Wright (2000), in his experiment on 'Fairchild' mandarin observed a reduction in titratable acidity due to girdling in the first year but no effect was observed in year 2 and 3. He also observed that November girdling led to increased fruit set and retention hence greater number of smaller fruits the first year while in the second year the fruits were few and larger. In the third year the yield was lower than control. In 'Aki'queen grapevines, girdling in the first year increased TSS and anthocynin content but this effect diminished on the second year. Onguso *et al.* (2005) in their experiment with peach found that brix was significantly higher in girdled trees for the first and second year but no difference was noted on the third year. He also observed that acidity was significantly reduced only in the first year and no effect was observed during the second and third year although the ring had not healed completely. Peng and Rabe (1996) in their experiment using 'Mihowase' Satsuma observed that girdling 2-5 weeks after the 'physiological fruit drop' (APFD) period significantly improved fruit color and TSS and showed no effect on yield and fruit size the first year but there was no effect on TSS and color the following year. Five weeks APFD girdled trees however significantly reduced fruit size compared to ungirdled the second year.

Notwithstanding, girdling has the potential to injure the trees to some extent and these girdles take considerable duration of time to heal the wound completely. The residual effect of this girdling on quality of Satsuma mandarin has not been studied. Since the literature cited show varied response between different fruits and also between cultivars of

the same fruit, this experiment was carried out to study the residual effects of partial girdling on fruit quality, three years after girdling in Satsuma mandarin.

MATERIALS AND METHOD

The present experiment was conducted in Satsuma fruit trees growing in the fruit orchard at the Ehime University Experimental Farm, Hojo located in southern Japan, 33°57' N, 132° 47' E at an elevation of about 20 m above sea level. The region has a mild temperate climate characterized by hot humid summers and cold dry winters. The soil at the experimental site is sandy loam (eutric fluvisol) with a pH (H20) of 5.7, a bulk density of a 1.08 gcm^{-3} and horizon A thickness of 0.15 m. The mandarin fruits trees used for this study had received 10cm girdling and 20cm girdling three years ago (2003) and the girdled wound had not been fully recovered by the third year. Five Satsuma mandarin fruit trees were used for the experiment. Each tree had 3 treatment units, 10cm partially girdled branch, 20cm partially girdled branch and ungirdled branch as control. The treatment was replicated in five trees. Thus, the experiment was laid out in the Randomized Complete Block Design (RCBD) with three treatments that were replicated three times.

For the evaluation of fruit quality, 20 fruits from each treatment branch were picked from all the replication, i.e. five trees. The fruits were weighed using physical balance. After that juice extraction was done by fruit destruction method, the soluble solids content in the juice was estimated using Automatic Temperature Correction Refractometer (Atago PR-1). The titratable acidity of juice was determined by acid-base titration method using 0.1 N NaOH using phenolphthalein as an indicator.

The data related to fruit quality were collected, tabulated and were analyzed using ANOVA test and separated by multiple range tests. For determining the effect on bark recovery, the bark that had regenerated was measured in all girdled branches of trees as a percentage of the total branch circumference. Thereafter, the values obtained for 10cm girdled fruit trees were compared with those of 20cm girdles using student t- test.

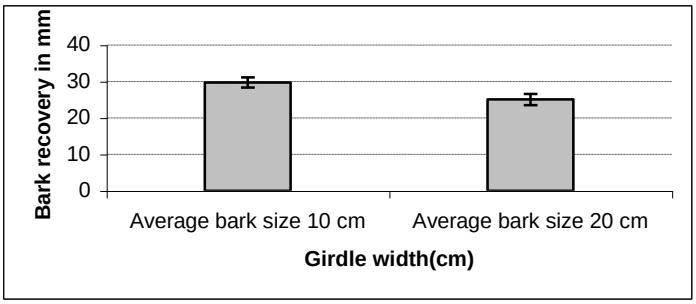

Fig.1: Girdle width influence on bark recovery in Satsuma mandarin

RESULTS

Bark recovery in the girdled portion

There was continuous and gradual recovery of the bark on the girdled portion of the branches of Satsuma mandarin tree. From the perusal of fig.1, it is apparent that the healing is in the faster rate in branches that received the treatment of 10cm girdling than in the branches receiving 20cm girdling. After three years of girdling operation, 10cm girdled branches had recovered 31% of the bark while 20cm-girdled branches had recovered 23% of the bark. Further, recovery of bark on the wounded portion of the stem is significantly higher in the branches receiving 10cm girdling than in the branches receiving 20cm girdling. Onguso *et al.* (2004) while working on peach also reported recovery of bark width on the stems those were subjected to the girdling. The bars are mean of recovered barks± standard errors. The means followed by same letter do not differ significantly by paired student t-test (n=4, p=0.01).

Fruit Quality

After three years of girdling operation, it was observed that the size of fruit did not vary in control than in the both of the girdled branches. The highest weight of fruit was recorded as 98.4 g as obtained in ungirdled branch while the lowest fruit weight of 93.0 g was recorded in branches that received the girdling treatment of 20cm width three years ago.

There was no difference in acidity of fruits obtained from girdled and non-girdled trees. Yamane and Shibayama (2006) working on 'Aki Queen' grapevine, Peng and Rabe (1996) on 'Mihowase' satsuma and Onguso *et al.* (2005) on peach made similar observation.

Table 1: Residual effect of 10cm and 20cm partial girdling on quality of Satsuma mandarin fruit

Treatment	Fruit weight (g)	Acidity (%)	TSS (%)
Control	98.4±3.52	1.1±0.05	10.0 ± 0.12
10cm girdle	97.4±2.33	1.1±0.04	10.5 ± 0.25
20cm girdle	93.0±4.18	1.1±0.10	10.4 ± 0.25

Values are means ± standard error. Means do not differ significantly from one another (p=0.05) by use of ANOVA test and multiple range test (n=4).

Brix levels of fruits harvested from the partially girdled trees were higher than control although the difference was not statistically significant. Yamane and Shibayama (2006) working with grapes found similar results in the second season while Onguso *et al.* (2005) working on peach found that Brix was significantly higher in girdled trees the first two years but the difference was not significant in the third year although the ring had not completely healed. Furthermore, there was no difference in total soluble content of fruit between 10cm and 20cm girdling treatment indicating that wider girdles do not enhance the effect of girdling over the longer duration after the imposition of treatment. It may be due to the fact that the influence of girdling on quality improvement diminishes gradually over time as the bark healing process occurs.

DISCUSSION

Although 10cm and 20cm girdling treatments resulted in significant increase in soluble solid concentration along with the decrease in acidity of fruit in the girdling year, its effect seems to reduce as the bark healing process takes place and speed up over time. The effect was not significant in the third year even though the bark was not fully regenerated. Brix and acidity of 10cm girdling were not different from those of 20cm girdle indicating that there is no advantage conferred by larger girdle to fruit trees. Since large girdle will take a longer time to heal and causes more injury to the tree, if girdling is to be used for fruit improvement, a smaller girdle that heals within the same year is preferable to enable the tree to regain its vigor within shorter duration of time.

From this experiment, it has been observed that the girdles reduced fruit size slightly, with 20cm girdle reducing the size more than 10cm girdle. This may be due to increased fruit set in the ungirdled and 10cm girdled branches than in the 20cm girdled branches although we did not count the fruits to determine yield per treatment branch. In addition it may also be due to the reduced vigor of the branch resulting from wider girdling / wounding in those branches. The fruits, however, were all of medium size and hence of good market value. Yamane and Shibayama (2006), Wright (2000) and Peng and Rabe (1996) have also made similar observations in their experiment related to girdling.

CONCLUSION

The size of a girdle determines how long it takes for the girdle to heal. In this study, 10cm and 20cm girdled branches of Satsuma mandarin had recovered 31% and 23% of its bark

respectively after 3 years of girdling. Fruit qualities were assessed to determine whether the delay in recovery had any effect on fruit quality. Wider girdles while being more injurious to the fruit tree than smaller girdles did not improve the fruit quality significantly in Satsuma mandarin in the third year. Therefore, the girdles that heal within one season might be more preferable to improve the quality of Satsuma mandarin fruit.

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