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RELATIONSHIP OF LEAF POSITION AND CO_2 ASSIMILATION WITH FRUIT GROWTH IN LITCHI

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SUMMARY

An experiment was conducted on 22-years old 'Bombai' litchi (*Litchi chinensis* Sonn.) trees to study the retention and development of fruit in relation to assimilate supply. One week after fruit set, bearing panicles were manually adjusted to achieve leaf/fruit ratio of 0 to 6 by careful removal of leaf or fruit or both, on girdled as well as ungirdled branches. The results suggested that four leaves behind the panicle essentially supported retention and development of a litchi fruit. However, on ungirdled, defoliated (leaf:fruit=0) branches the developing fruits showed ability to draw resources from rest of the tree's carbon balance. The leaves just behind the fruit cluster were more effective for supplying assimilates to developing fruit than those which were old and away from fruits.

Key words: **CO_2 assimilation, fruit retention, leaf:fruit ratio, litchi**

INTRODUCTION

The photosynthates from leaf (source) is translocated to the developing fruits (sinks), the economic part in litchi. Once the source-sinks relationships are understood, it may be possible to increase crop productivity by increasing the accumulation of photosynthate in edible sink tissues (Dunford 2002). Several researchers have studied the source-sink relationship in fruit crops, viz. apple (*Malus domestica*), pear (*Pyrus pyrifolia*), cherry (*Prunus avium*), grapefruit (*Citrus paradisi*, macadamia (*Macadamia integrifolia x M. tetraphylla*), mango (*Mangifera indica*) and litchi (*Litchi chinensis*) (Ropper *et al.* 1987, Proctor and Palmer 1991, Reddy and Kurian 1993, Trueman and Turnbull 1994, Roe *et al.* 1997, Teng *et al.* 1998). The effect of water deficits on current assimilation and yield of litchi was studied by Menzel *et al.* (1995) and Debnath *et al.* (2004). It has been observed that reduction in current assimilation rate due to water deficits reduced fruit retention, development of fruit and fruit yield $tree^{-1}$ at harvest. The maximum intensity of fruit drop between 1st and 3rd week after fruit set was also found positively correlated with the net CO_2 assimilation rate (Debnath *et al.* 2004), which suggests that manipulating the number and position of source leaves could have direct effect on the retention of fruit.

In the present experiment, the effect of variable number of leaves (different leaf:fruit ratio) and its position (relative distance from fruit cluster) on the development of a constant number of litchi fruits $panicle^{-1}$ (i.e., fixed sink capacity, on girdled or ungirdled branches was studied.

MATERIALS AND METHODS

Experiment was conducted on 22-years old 'Bombai' litchi trees at the Horticultural Research Station, BCKV in subtropical West Bengal (lat. 23.5°N), India in 2004.

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Treatments were arranged in a randomized complete block design, with four trees per treatments. One week after fruit set (WAFS), the branches (2-3 cm in diameter) were girdled approximately 1.0 m from the fruit cluster to separate the girdled branches from the carbon balance of the tree. The ratio of number of leaves on the fruiting branch of about 1.0 m length from fruit cluster and number of fruitlets per cluster varied between 3 and 6 at 1 WAFS. We adjusted the ratio at 0, 1, 2, 3, 4, 5 and 6 by hand removal of leaf or fruit or both on girdled and ungirdled branches. For adjustment of leaf fruit ratio on girdled branches, leaf removal started with the leaf nearest to the girdled site and progressed upwards as per requirement. In ungirdled branches, the required number of leaves were retained starting with the leaf just beneath fruit cluster and retention progressed downwards. The excess leaves within 1.0 m length of branch were removed. When it came for fruit removal in a heavy set cluster to achieve the required leaf fruit ratio, crowded ones were stripped off. Thus, the leaf: fruit ratios of 0 to 6 both on girdled and ungirdled branches were studied in relation to current assimilation rate on fruit retention and development of fruit. Carbohydrate content of leaf and shoot at fruit set were estimated as 6.80 and 11.90 %, respectively and again estimated after harvest. The CO_2 assimilation rate was measured with a portable photosynthesis meter (Cl-310, CID, Inc., USA) at 15 days interval. The records on fruit retention and fruit weight have been presented as treatment means. The data were analyzed for statistical inference (Gomez and Gomez 1983).

RESULTS AND DISCUSSION

The carbon economy of girdled branches was totally isolated from that of the tree and therefore, the leaves below the fruit cluster were virtually the only source of assimilate supply for developing fruits. Variations in leaf numbers per fruit thus supposed to have a direct influence on fruit development. In contrast, the un-girdled branches were un-separate parts of the tree's carbon balance and therefore, it may be assumed that the source of assimilate supply would not be restricted only to the leaves below the fruit cluster.

The net CO_2 assimilation rate was higher on the girdled branch compared with the ungirdled branch. On the girdled branches, the net CO_2 assimilation rate varied between 8.78 and 10.61 µmol $m^{-2}s^{-1}$ due to different leaf: fruit ratios, while it was between 8.66 and 9.48 µmol $m^{-2}s^{-1}$ on the ungirdled branches (Table 1). However, the net CO_2 assimilation showed gradual decline with the decrease in leaf: fruit ratio from 1 to 6, both on the girdled and ungirdled branches. The highest net CO_2 assimilation was recorded when leaf: fruit ratio was 1 on the girdled branch compared with the lowest on ungirdled branch with a leaf: fruit ratio of 6. This increase in net CO_2 assimilation rate caused by girdling and lower leaf/fruit ratio was believed to be due to comparatively more demand of developing fruits under limited assimilate supply. Increase in leaf: fruit ratio indicates more distance of contributing leaves from the developing fruits. The leaves which are away from the fruit cluster are more aged with relatively low in leaf N content compared with the recently matured leaves which are close to the fruit cluster. The decline in photosynthesis is known to be associated with the decline in leaf N content (Peng *et al.* 1995).

Fruit retention was markedly reduced on girdled branches compared with ungirdled branches. Removal of all leaves (leaf/fruit=0) on girdled branches virtually failed to retain any fruit to maturity. There was a gradual decline in fruit retention on the girdled branch from 5.61% with a leaf: fruit ratio of 1 to 29.75% when 6 leaves were retained per fruit. The number of leaves between 4 and 6 per fruit caused retention of almost the same number of fruit (29.50 to 29.75%) per panicle which sharply declined to less than 18.5% due to a leaf: fruit ratio of 3 and below (Table 2). The results thus indicated that retention of fruit was principally dependent on current assimilation (Roe *et al.* l997, Debnath *et al.* 2004) which was essentially supported by atleast four leaves behind the panicle for retention of each fruit. However, the effect of leaf: fruit ratio on retention of fruit on ungirdled branch varied between 29.80 due to a leaf: fruit ratio of I and 32.75% with a leaf: fruit ratio of 6. Absence of a source leaf (leaf: fruit =0) for current assimilation supply virtually could not retain any fruit on the girdled branch compared with 29.80% on the ungirdled branch. The retention and development of fruit at a low leaf: fruit ratio on the ungirdled branch would therefore, be possible with the supply of assimilate translocated from elsewhere of the tree. The possibility of this type of distribution of

Table 1. Variations in net CO_2 assimilation rate (µmol $m^{-2}s^{-1}$)) in leaves due to its position and different leaf: fruit ratios on girdled and ungirdled branches of litchi

Treatment	On girdled branch			On ungirdled branch		
	3 WAFS	5 WAFS	7 WAFS	3 WAFS	5 WAFS	7 WAFS
T_1 (Leaf: Fruit ratio=1)	9.48	7.50	6.55	8.88	7.10	6.28
T_2 (Leaf: Fruit ratio=2)	9.23	7.53	6.43	8.68	6.63	5.33
T_3 (Leaf: Fruit ratio=3)	8.33	6.18	4.50	7.78	6.48	4.03
T_4 (Leaf: Fruit ratio=4)	6.60	5.00	4.35	5.58	4.98	3.95
T_5 (Leaf: Fruit ratio=5)	4.25	3.33	2.95	4.10	3.10	2.75
T_6 (Leaf: Fruit ratio=6)	3.85	3.08	2.73	3.68	3.18	2.50
SEm (±)	0.525	0.495	0.427	0.364	0.573	0.491
C.D. at 5%	1.091	1.060	0.984	0.990	1.140	1.056

Table 2. Effect of leaf number and its position on fruit retention, average fruit weight and fruit yield per panicle on girdled and ungirdled branches of litchi

Treatment	On girdled branch				On ungirdled branch			
	No. of fruit/panicle at harvest	Final fruit retention (%)	Average fruit weight (g $fruit^{-1}$)	Yield (g $panicle^{-1}$)	No. of fruit/panicle at harvest	Final fruit retention (%)	Average fruit weight (g $fruit^{-1}$)	Yield (g $panicle^{-1}$)
T_0 (Leaf: Fruit ratio=0)	0.98	6.53	20.83	20.28	11.93	79.53	22.13	263.96
T_1 (Leaf: Fruit ratio=1)	2.25	15.00	21.10	47.58	12.25	81.67	22.20	272.26
T_2 (Leaf:Fruit ratio=2)	4.38	29.20	21.40	93.20	12.35	82.33	22.40	276.74
T_3 (Leaf:Fruit ratio=3)	7.38	49.20	21.73	160.10	12.95	86.33	22.45	290.83
T_4 (Leaf:Fruit ratio=4)	11.83	78.87	23.15	273.80	13.03	86.87	23.13	301.16
T_5 (Leaf:Fruit ratio=5)	11.88	79.20	23.20	275.32	13.08	87.20	23.25	303.88
T_6 (Leaf:Fruit ratio=6)	11.90	79.33	23.25	276.72	13.10	87.33	23.23	304.01
SEm(±)	0.723	-	0.390	354.79	0.29	-	0.273	206.54
C.D. at 5%	1.260	-	0.930	27.99	NS	-	NS	21.36

assimilate was demonstrated in apple using isotopic ^{14}C that translocated from non-fruited branch to the developing fruit, especially those with a low leaf: fruit ratio (Hansen 1969).

The leaf : fruit ratio showed significant effect on the average weight of fruit on the girdled branches, while the effect was non-significant on ungirdled branches (Table 2). The fruit weight was below 23g when the number of supporting leaves per fruit was less than 4, both on girdled and ungirdled branches. In absence of a supportive leaf on a girdled branch, very few fruits (<2.5%) that retained, remain under-developed. The development of fruit was sub-optimal (<21.8g on girdled branch and < 22.5g on ungirdled branch) even when the number of supportive leaves per fruit increased from 1 to 3. However, the leaf: fruit ratio of 4, 5 and 6 produced the fruits of almost similar in weight (23.10 to 23.25g), irrespective of girdling. The yield of fruit per panicle varied significantly both on girdled and ungirdled branches due to the variation in leaf number per fruit. Yield was negligible (20.7 g/panicle) on the girdled branch in absence of leaf, which increased gradually with leaf number from 47.5g/panicle (leaf : fruit=l) to 276.70g/ panicle (leaf : fruit=6). However, the yield was very close (274.0 to 276.7g/panicle) when the number of supportive leaves varied between 4 and 6. In contrast, the fruit yield was 263.7g/panicle on ungirdled branch even in absence of a supporting leaf behind the fruit cluster. Retention of one leaf per fruit produced only 272.0g fruit/panicle compared with 301. 5 - 304.2 g fruit/panicle due to more number of leaves (4-6) per fruit (Table 2). Similar source-sink relationship was also reported by Roe *et al*. (1997) and Hieke *et al.* (2002).

The fruits on girdled branch turned red peel colouration much earlier than that on the non-girdled branch. The peel anthocyanin content was much higher (20.3 to 21.9 mg/l00g) due to girdling compared with 18.3 to 19.1 mg/100g peel of fruit on ungirdled branch (Table 3). The ethylene mediated accumulation of anthocyanin in fruit epidermis, stimulated by physical injuries (girdling and leaf removal) might be the possible reason (Kieber 2002). In general, the total soluble solids (TSS) and total sugars (TS) content were higher (17.2 to 18.5°B and 15.1 to 15.7%, respectively) in aril of fruits that developed on ungirdled branch compared with 16.0 to 18.2ºB and 14.3 to 15.3%, respectively due to girdling. The number of source leaves per fruit significantly influenced the TSS and TS content of fruit. Absence of source leaf on girdled branch caused the minimum TSS (16.0ºB), TS (14.3%) and TSS/acid ratio (38.1) of fruit, while six leaves per fruit on ungirdled branch caused the maximum TSS (18.5^0B), TS (15.7%) and TSS/acid ratio (41.8) of fruit. The TSS and TS content of fruit showed gradual decline with decreasing number of source leaves per fruit. A limited supply of assimilate appear to hinder the development of fruit (Debnath *et al*. 2004) due to the lower leaf: fruit ratio and girdling.

At fruit set, the carbohydrate content of leaf and shoot were 6.80 and 11.90%, respectively which declined after harvest both on girdled and non-girdled branches. However, the reserves of carbohydrate depressed more due to girdling during fruit development compared with the ungirdled branch. The carbohydrate content of leaf and shoot were less than 5.4 and 10.1%, respectively on the girdled branch due to a leaf: fruit ratio of 3 and below. But it was higher (6.3 to 6.7% and 10.5 to 11.5%, respectively) in case of ungirdled branch after harvest (Table 4). Fruit development process caused maximum depletion in carbohydrate reserves of shoot (from 11.9 to 9.3%) on girdled branch in absence of any source leaf or presence of only one source leaf per fruit, compared with the minimum depletion (from 11.9 to 11.5%) due to presence of 5 or 6 source leaves per fruit on ungirdled branch (Fig.4). It appears that at lower leaf: fruit ratio, the developing fruits on the girdled branch had the ability to draw assimilate supply from elsewhere of the tree but on the girdled branch, the developing fruit utilized the reserve carbohydrate in shoot and to some extent from the leaf.

It may be summarized that the retention and yield of fruit were reduced by 37 to 92% and 41 to 92%, respectively when the number of source leaves per fruit was less than 4 (leaf: fruit <4), suggesting that four leaves behind the fruit cluster essentially supported the retention and development of a litchi fruit. However, increasing the number (> 4) of leaves per fruit was not much effective for increased retention and yield of fruit. These results perhaps indicate the relative capacity of leaf in assimilate supply for fruit development. It appears that the leaves just behind the fruit cluster are more effective

Table 3. Effect of girdling and leaf: fruit ratio on yield parameters and quality of fruit of litchi

Treatment	Anthocyanin (mg/100 g peel)	Total soluble solids (°B)	Total sugars (%)	TSS/ acid ratio
Girdled branch				
Leaf: fruit=0	21.90	16.00	14.30	38.10
Leaf: fruit=1	20.80	16.60	14.50	38.10
Leaf: fruit=2	20.80	16.80	14.50	39.10
Leaf: fruit=3	20.70	17.00	14.80	39.40
Leaf: fruit=4	20.60	18.10	15.20	40.20
Leaf: fruit=5	20.40	18.20	15.30	40.40
Leaf: fruit=6	20.30	18.20	15.30	40.40
Ungirdled branch				
Leaf: fruit=0	19.10	17.20	15.10	40.00
Leaf: fruit=1	18.70	18.10	15.30	41.10
Leaf: fruit=2	18.60	18.20	15.40	41.40
Leaf: fruit=3	18.40	18.40	15.60	41.70
Leaf: fruit=4	18.40	18.40	15.70	41.70
Leaf: fruit=5	18.30	18.40	15.70	41.80
Leaf: fruit=6	18.30	18.50	15.70	41.80
C.D. at 5%	1.01	0.43	0.40	–

Table 4. Variations in carbohydrate content in leaf and shoot due to different leaf: fruit ratios on girdled and ungirdled branches of litchi at harvest

Treatment	On girdled branch		On ungirdled branch	
	leaf (% dry wt.)	Shoot (% dry wt.)	Leaf (% dry wt.)	Shoot (% dry wt.)
T_1 (Leaf: Fruit ratio=1)	3.28	9.28	4.60	9.58
T_2 (Leaf: Fruit ratio=2)	3.40	9.40	4.65	9.58
T_3 (Leaf: Fruit ratio=3)	3.43	9.38	4.73	9.68
T_4 (Leaf: Fruit ratio=4	4.15	9.80	5.40	10.18
T_5 (Leaf: Fruit ratio=5)	4.35	9.83	5.68	10.23
T_6 (Leaf: Fruit ratio=6)	4.53	9.85	5.70	10.23
SEm (±)	0.191	0.085	0.292	0.079
C.D. at 5%	0.659	0.431	0.815	0.420

than those are old and away from the fruit. In case of ungirdled branch, the retention and development of fruit were comparatively less dependant on the number and position of leaf Depletion in carbohydrate reserves of leaf and shoot during fruit development was less compared with girdled branches. These results indicate that the demand pool for assimilate by developing fruits was met from the whole carbon balance of the tree to which the branch was intact.

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