リンゴ‘ふじ'における成り枝の果実生産性に関する研究

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Studies on Yield Efficiency of Fruiting Units in 'Fuji' Apple Trees

Takenori Asada

Faculty of Agriculture and life science, Hirosaki University, Hirosaki 036-8561

Summary

The influences of shoot growth, composition of 1- and 2-year-old branches, and fruit set on yield efficiency of fruiting branches in 'Fuji' apple trees / Marubakaido (*Malus prunifolia* Borkh. var. *ringo* Asami), trained to an open-center shape, were investigated.

The efficiency of fruiting branches expressed as the number of fruits per unit of total leaf area (FLA, Fruits/m^2)(per branch) varied from 0.7 to 13.3 with an average value of 5.0 for all branches. Age, orientation, elevation above the ground, and vigor of fruiting branches did not account for a large portion of the variations in the efficiency of fruiting branches. A strong inverse relationship exists between Log_{10} FLA and bud production rate (BPR)(shoot count per 1-yr-old branch). BPR is positively correlated to leaf area per 1-yr-old branch ($r \geqq 0.807^{**}$). Leaf area per 1-yr-old branch decreased with; 1) increasing proportions of terminal spur on 1- and 2-yr-old branches and 2) decreasing long axillary on 1- and 2-yr-old branches. Leaf area per 1-yr-old branch increased rapidly below 30 % of the short terminal on 1-yr-old branch (terminal spurs). The regression equations for Log_{10} FLA on BPR differed significantly among trees but not in the slopes. Tree with the highest FLA across all BPR had the highest fruit set.

Key Words: fruit number, leaf area, *Malus*, shoot number, wood composition.

Introduction

The fruiting units of apple trees are comprised of older branches, bourses (spurs), current shoots, and leaves (Forshey and Elfving, 1979). The performance of these fruiting branches affects yield and quality of apple fruits (Lespinasse and Delort, 1986). Tustin et al.(1988) reported that pendant lateral branches produced fewer and smaller fruits per flowering spur than did horizontally or vertically oriented ones, indicating that yield is dependent on many factors including light penetration. Branch age influences fruit size (Denne, 1963; Jackson, 1970) and soluble solids (Robinson et al., 1983). However, the effects of branch orientation and age on performance of fruiting branches are inevitable for trees with large canopy volume. Therefore, growers have adjusted and directed branch growth by pruning to minimize negative effects. It is important to identify fruiting branches with high efficiency to provide practical procedures of pruning. This study was conducted to determine the relationship between yield efficiency and such components as 1- and 2-yr-old branches and shoots. The efficiency of fruiting branches is expressed as fruit count per total leaf area. The efficiency of fruiting branches or trees is determined by yield and branch size. Yield is closely related to the number of fruit (Asada, 1988; Forshey and Elfving, 1977). Although tree and branch sizes have been expressed by their cross sectional diameter or area, canopy volume or leaf area (Ferree, 1980), leaf area seems to be a better basis than the others because the cross section loses its close relationship with tree sizes by severe pruning and canopy volume is not easy to measure precisely.

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Materials and Methods

Four 22-yr-old and an approximately 50-yr-old 'Fuji' apple trees on Marubakaido (*Malus prunifolia* Borkh. var. *ringo* Asami), trained to the open center system, were selected from 5 commercial orchards located near Hirosaki, Aomori Prefecture. The trees examined had been managed intensively with adequate procedures to bear high-quality fruit regularly. Data were collected from all fruiting branches on the trees in August and September in 1983. Mean circumference and age ($\pm$ SD) of fruiting branches (n=158) were 18.0 $\pm$ 5.2 cm and 9.1 $\pm$ 2.2, respectively. Orientation and position (height above ground surface) of fruiting branches and number of fruit, number and length of terminal and axillary shoots, and 1- and 2-yr-old branches on each fruiting unit were measured. 1- and 2-yr-old branches were classified by their length ; short ($\leqq$ 5.0 cm), middle (5.1-10.0 cm) and long (>10.0 cm). Shoot leaf areas were estimated by a regression equation between shoot length and leaf area obtained from each tree. Leaf area on bourses (spur) were determined by multiplying the average leaf area per bourse and the total number of bourses. Total leaf area of a fruiting unit was

then calculated by adding the shoot leaf area to the bourse leaf area.

Results and Discussion

1. Within-tree variations in fruits per leaf area (FLA)

FLA have been used as a measure of physiological efficiency of apple trees. Ferree (1980) found that in the upper third of a canopy, FLA was higher than those in the middle and lower third in 'Golden Delicious'. In this study, FLA varied from 0.7 to 13.3 among trees with a mean of 5.0 (Fig. 1). The mean value corresponds to FLA found by Ferree in the lower third of a canopy. It seems that the relatively low FLA obtained in this study reflects a cultivar effect and the difference in desirable fruit size (Asada, 1989). The tree-to-tree and the within-tree variability in FLA were considerable, so that the sources of the variations were analyzed as follows.

Table 1. Correlation between branch age, orientaion, height above ground surface, and vigor with fruits per leaf area (FLA) for 'Fuji' apple.

Items	Correlation coefficients (r)
Age	0.446**
Orientaion[z]	0.305**
Height	-0.051
Branch vigor[y]	-0.314**

[z] Angle of fruiting branches, vertical=0°.
[y] Mean length of terminal shoots produced from terminal 1-yr-old branches.
** Significant at P = 0.01 level.

2. Effects of age, orientation, elevation above ground surface, and vigor of fruiting branches on FLA

The correlations of FLA with various parameters of measurement for fruiting units (Table 1) reveal that FLA tends to increase with increasing branch age (r=0.446**); it was especialy low in branches less than 6-yr-old (Fig. 2). But other factors such orientation, elevation, and branch vigor were not closely related to FLA. A number of studies (Lespinasse and Delort, 1986; Tustin et al., 1988; Myers and Ferree, 1983) have shown that these factors influence comparative yield and fruit quality in apple. However, in this study , these factors, including branch age, contributed a small proportion to FLA variation among fruiting branches. Consequently, fuiting units may be modified to achieve a desirable physiological efficiency by intensive pruning on these trees.

3. Effects of components of fruiting branches on FLA

1) Relationship between FLA and bud production rate (BPR)

BPR was determined as shoots per 1-yr-old branch (shoots・bud^{-1}). Log_{10} FLA was negatively related to BPR with a different regression line for each tree (Fig.3). This relationship is based on the following conditions; (1) fruits born terminally on 1-yr-old branch are left intact while others are thinned,(2) fruits / total 1-yr-old branches (fruit set) have an upper limit due to the negative effect on flower bud formation (Koike et al., 1990), and (3) leaf area per 1-yr-old branch increases with an increase in BPR. In this study,

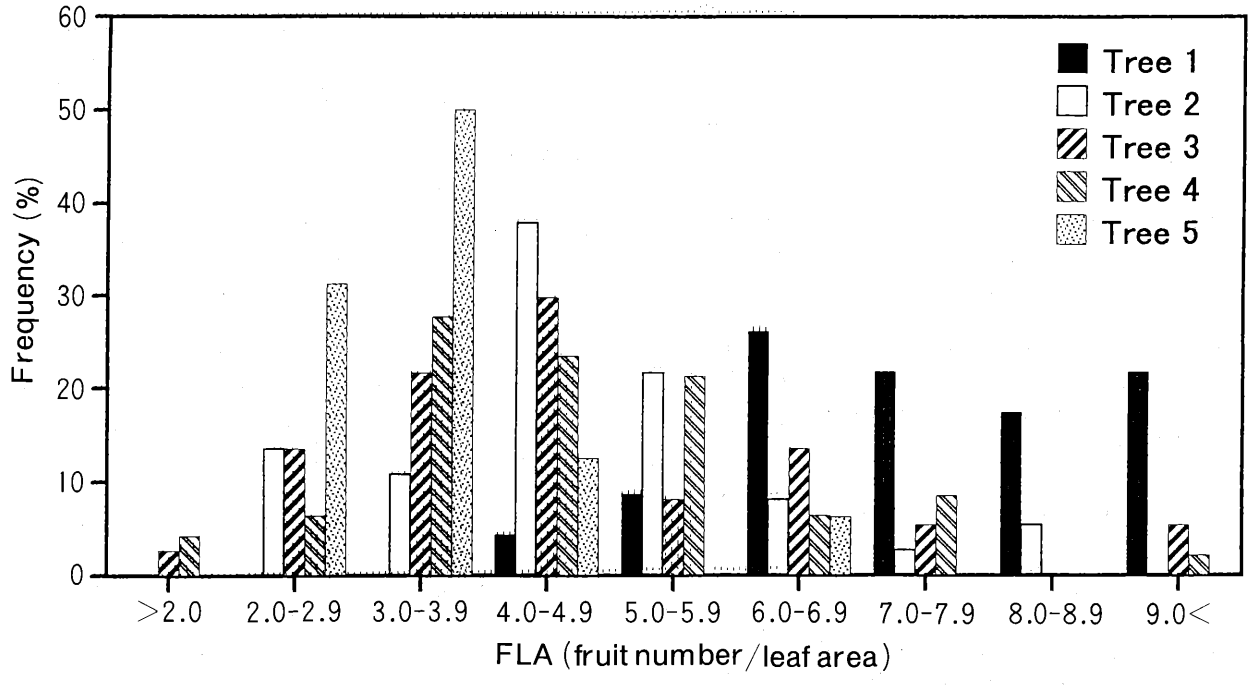


Fig. 1. Distribution of fruit number per leaf area (FLA) within and among 'Fuji' apple trees.

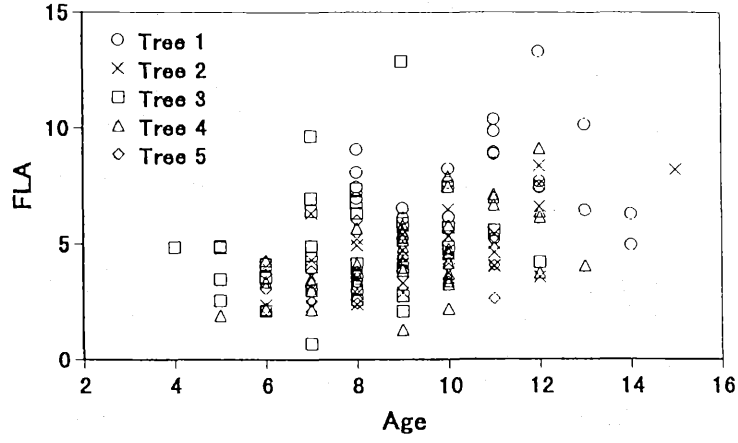


Fig. 2. Relationship between fruit number per leaf area (FLA) and branch age in 'Fuji' apple.

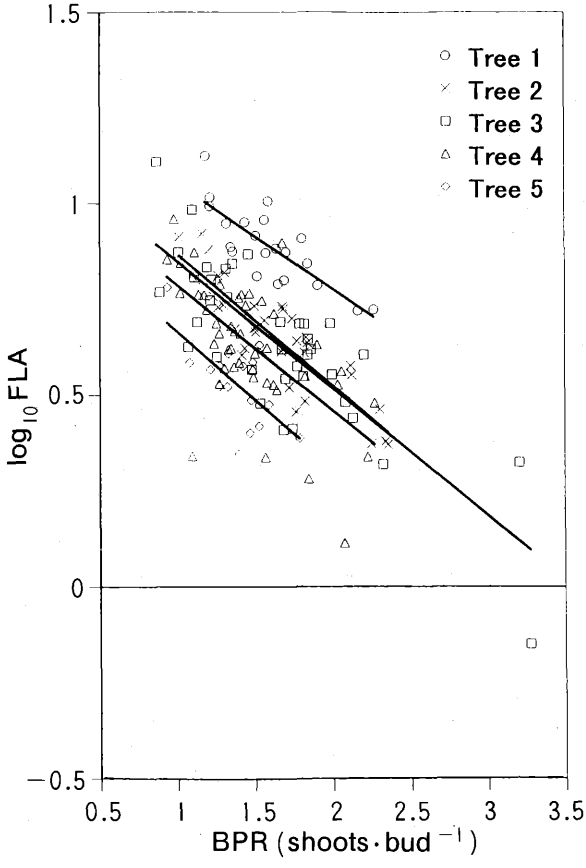


Fig. 3. Relationship between $\log_{10}$ FLA (fruits per leaf area) and bud production rate (BPR) in 'Fuji' apple. Each point represents a fruiting branch. Equation for the line of best fit is as follow:

Tree 1: y=1.33 − 0.28x, r=−0.821**
Tree 2: y=1.21 − 0.34x, r=−0.800**
Tree 3: y=1.18 − 0.33x, r=−0.873**
Tree 4: y=1.12 − 0.33x, r=−0.624**
Tree 5: y=1.02 − 0.35x, r=−0.663**

a close positive relationship between BPR and leaf area per 1-yr-old branch was obtained in each tree examined (Fig. 4), whereas a negative relationship between $\log_{10}$ FLA and BPR confirms the importance of decreasing BPR and leaf area per 1-yr-old branch to improve the efficiency of fruiting branches. Porter and Llewelyn (1984) found that a strong inverse relationship existed between the proportion of buds that escaped pruning and the $\log_{10}$ of their subsequent production rate (BPR). As in their trial, cut-back (heading) pruning was performed but such pruning may not increase FLA, except for weak branches on which fruit quality begins to suffer.

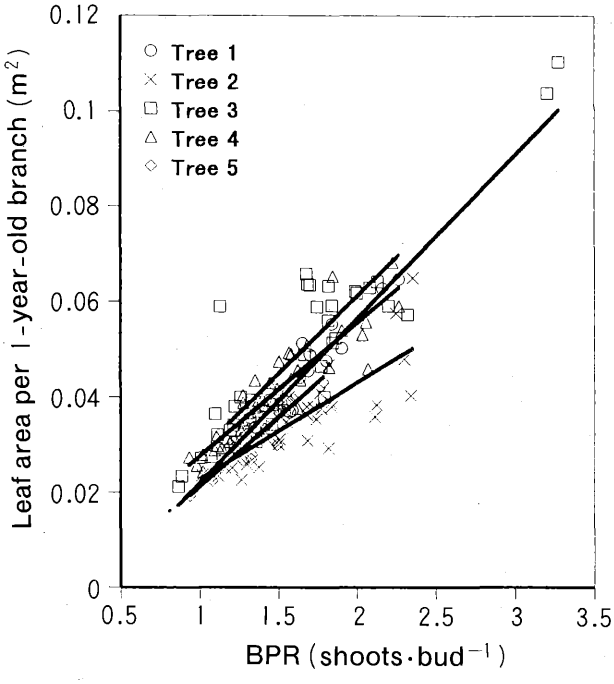


Fig. 4. Relationship between leaf area per 1-yr-old branch and bud production rate (BPR) in 'Fuji' apple. Equation for the line of best fit is as follow:

Tree 1: y=−0.004+0.03x, r=0.909**
Tree 2: y= 0.003+0.02x, r=0.807**
Tree 3: y=−0.013+0.03x, r=0.960**
Tree 4: y=−0.0002+0.03x, r=0.908**
Tree 5: y=−0.008+0.03x, r=0.867**

2) Factors affecting leaf area of 1-yr-old branches

It is thought that pruning that does not cause a large increase in BPR or maintains BPR at a relatively low level may contribute to an increase in FLA. Because BPR is closely related to the leaf area per 1-yr-old branch, the factors affecting the leaf area were determined. One- and 2-yr-old branches were classified into four types by length and position (terminal and axillary) respectively (Fig. 5). The data (Table 2) show the relationships between the percentage of each type of branch per fruiting unit and the mean leaf area per 1-yr-old branch in fruiting units. The mean leaf area per 1-yr-old branch was correlated positively with the percentages of long axillary 1- and 2-yr-old branches, and negatively with those of short terminal 1- and 2-yr-old branches. On the other hand, the percentages of long terminal and short axillary 1- and 2-yr-old branches were not related to the mean leaf area per 1-yr-old branch. These results indicate that the fruiting branches composed of relatively low proportions of long axillary branches and of relatively high proportions of short terminal branches can have a high FLA. Maggs (1959) found that pruning decreased the proportion of short to long shoots in young apple trees. However, depending upon the type of branch removed and its location, pruning has a possibility of increasing the number of short terminal branches in the tree as it begins to bear. A method of pruning should be selected to obtain the desired response. Such pruning might be 'long lateral-branch pruning,' namely, long 1- and 2-yr-old branches, originating from axillary positions on the parent branches, should be thinned to such a degree that they do not induce excessive vegetative growth. Long lateral branches tend to produce one or more long shoots and devitalize the short branches near the base; removal of long laterals does not stimulate excessive growth of remaining buds as compared to eliminating long terminal branches. Thus, the proportion of short to long terminals on 1- and 2-yr-old branches should be maintained at a relatively high level by such pruning.

Leaf areas on 1-yr-old branches increased rapidly below 30 % of the terminal spurs (Fig. 6). Thus an optimum pruning strategy would be to leave 30 % of the terminal spurs.

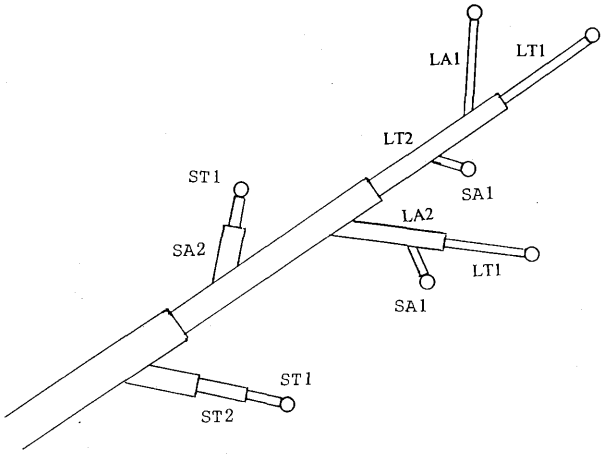


FIg. 5. A diagram showing of the branches classified in Table 2 after pruning and before shoot growing. LT*, LA*, ST* and SA* indicate long terminal, long axillary, short terminal and short axillary branch, respectively. Numerals of 1 or 2 with the asterisk indicate 1-yr-old and 2-yr-old, respectively.

Table 2. Correlations between the percentage of each type[z] of 1- and 2-yr-old branch and the mean leaf area per 1-yr-old branch in fruiting unit of 'Fuji' apples.

Branch type			Correlation coefficients (r)
Age	Length[y]	Position	
1	Long	Terminal	-0.031
1	Long	Axillary	0.547**
1	Short	Terminal	-0.597**
1	Short	Axillary	0.188
2	Long	Terminal	-0.301**
2	Long	Axillary	0.524**
2	Short	Terminal	-0.469**
2	Short	Axillary	-0.066

[z] Types of 1- and 2-yr-old branches are shown in Fig. 5.
[y] Long:>10 cm, short: ≦ 5 cm.
** Significant at P = 0.01 level.

3) Tree-to-tree variation in relationship between FLA and BPR

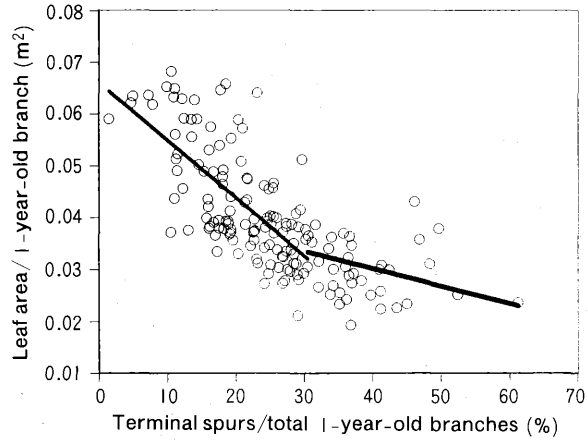


Fig. 6. Relationship between leaf area per 1-yr-old branch and the percentage of terminal spurs in 'Fuji' apple fruiting branches. Equation for the line of best fit is as follow:
Below 30 % of terminal spur: y=0.07-0.001x,
r=-0.729**
Above 30 % of terminal spur: y=0.04-0.0004x,
r=-0.409**

Table 3. Mean FLA, fruit set, flower bud formation, propotion of spur and branch vigor of five 'Fuji' apple trees.

Parameters	Tree no.				
	1	2	3	4	5
FLA	7.97a[z]	4.72b	4.82b	4.64b	3.49c
Fruit set (%)	32.3a	15.7d	21.3b	17.8c	10.9d
Flower bud formation (%)	82.6ab	68.2c	84.4ab	89.1a	80.6b
Proportion of spur (%)	74.8b	81.0a	75.5b	81.1a	82.1a
Branch vigor (cm)[y]	26.7c	35.3ab	36.9a	30.0bc	30.1abc

[z] Mean separation within trees by Sheffe's F test, 5% level.
[y] Mean length of terminal shoots produced from terminal 1-yr-old branches.

In the relationship between $\log_{10}$ FLA and BPR, there was a significant difference between the regression line for each tree, but the slopes of the lines are nearly parallel (Fig. 3). Across the range of BPR obtained, fruiting branches on tree 1 had a significantly higher FLA than those from the other trees, suggesting that tree 1 has some factors which increased FLA of the fruiting units as compared with other trees. The comparison between trees was made about the parameters relating to fruit bearing (Table 3). Tree 1 had a significantly higher fruit set than the other trees. However, such factors as the proportion of spurs, flower bud formation and branch vigor did not contribute to the high FLA in tree 1. There is a general observation that larger and better-colored fruits are borne on thick wood than on thin wood (Christopher, 1974). The high fruit set in tree 1 may have resulted from the high proportion of thick spurs on the fruiting units.

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リンゴ‘ふじ’における成り枝の果実生産性に関する研究

浅田武典

弘前大学農学生命科学部　036－8561　弘前市文京町3

摘　要

リンゴ‘ふじ’における成り枝の果実生産性を葉面積当たり果数(FLA)として測定し，FLAに及ぼす芽の増加率(BPR)，1，2年枝の長さ別分布割合，新梢生長及び着果率の影響を明らかにするため，良品生産を維持している生産者園の開心形成木樹について検討した．

全成り枝のFLAは0.7から13.3まで分布し，平均値は5.0であった．成り枝の年齢，発出部位高，発出角度，栄養生長の強さはFLAの変異を説明する主要な要因ではなかった．FLAと芽の増加率(BPR)の間には負の相関関係が認められた．BPRの増加は1年枝当たり葉面積の増加を伴う($r \geqq 0.831^{**}$)ため，1年枝当たり葉面積を増加させる要因について検討した結果，1，2年生えき生長枝(>10 cm)の割合が低いほど，また1，2年生頂生短枝($\leqq 5$ cm)の割合が増加するほど1年枝当たり葉面積が大きくなることを認めた．1年生頂生短枝(頂生スパー)の1年枝に占める割合が30%以下になると，1年枝当たり葉面積が急激に増加した．FLAとBPRの関係は供試樹間で違いがみられ，BPRに対し常に高いFLAを有する木は着果率(全1年枝に対する着果した1年枝の割合)が高かった．