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Production Capacity Evaluation of the Citrus Tree by the Optical Method

By

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Summary

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In order to evaluate citrus tree productivity by remote sensing, a nondestructive method that estimated the leaf area index per tree crown area (LAI_{tca}) using a plant canopy analyzer (PCA: LAI-2000, LI-COR, Inc.) was examined.

The measurement by the PCA was carried out in 2003 and 2004 on 7 kinds of Satsuma mandarin (*Citrus unshiu* Marc.) tree of which cultivar, tree age and size differed. The cultivars used for the experiments were Otsu No.4, Sugiyama unshiu and Okitsu wase. To begin with, PCA measured the incident light to the treetop, and next, it measured the transmitted light of the tree at the 30cm interval (30, 60, 90, 120, 150, 180cm) on 4 azimuths (NE, NW, SE, SW) from the trunk. The measurement was carried out under cloudy conditions in order to minimize the effect of the direct light to the PCA. After the measurement, total leaf numbers, average of individual leaf area, tree crown radius in the 16 or 8 azimuths and tree height of the trial tree were measured.

From total leaf area, tree crown area and tree height, LAItca and leaf area density (LAD) were calculated. The LAI_{tca} is the result of dividing the total leaf area by the tree crown area, and the LAD is the result of dividing the LAI_{tca} by tree height. The leaf area index (LAI) by the PCA was recalculated except for the values of the measuring point which was outside the tree crown area. In the relationship between LAI by PCA and LAI_{tca}, there was an underestimation tendency of about 37%, but the very high correlation was shown when the lower LAD trees were removed. The possibility of LAI by PCA using this measurement method as an effective index for LAI_{tca} in productivity evaluation of the citrus tree was indicated.

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Introduction

A serious problem of citrus cultivation in Japan is that annual fluctuations of yield and price are large due to alternate-bearing, which makes management unstable and lowers the profitability of farmers. Alternate-bearing is a phenomenon in which a tree alternates between heavy production one year to fewer fruit the next. While a tree forms fruit on a branch, the flower bud in the next year has formed on the equal branch. So, the quantity of the flower bud in the next year becomes poor, when superfluous fruit production in some years is carried out. As factors that promote alternate-bearing, the following were raised: dense planting and weakness of tree vigor by aging, insufficient bearing management and moisture and soil management, etc.. Understanding the condition of trees and cultivation management in proportion to the condition are necessary in order to avoid alternate-bearing. It is necessary to ensure a fructification number that is suitable for the production capacity of the tree and to recover tree vigor through appropriate cultivation management.

The leaf area index (LAI) has become an important index of the growth situation and production capacity of the plant. The survey of total leaf area for citrus trees reqires considerable labor and time in order to calculate by the product of average individual leaf area and the total number of leaves. A plant canopy analyzer (PCA: LAI-2000, LI-COR, Inc.) calculates LAI from radiation measurements made with a "fish-eye" optical sensor (WELLS & NORMAN 1991). It is reported that the highly precise estimation is already possible for the PCA in herbaceous crop canopies such as rice, wheat and soybean (IWAYA & YAMAMOTO 2004, WELLS & NORMAN 1991, YAMAMOTO & al. 1995). It is also utilized for the leaf area evaluation of forests (GRACE & FOWNES 1998, NACKAERTS & al. 2000, SMOLANDER & STENBERG 1996). In this study, a technique which estimates the leaf area index per tree crown area (LAItca) by a quick and nondestructive method using a plant canopy analyzer is examined in order to evaluate the tree productivity of isolated citrus trees.

Material and Methods

The measurement by the PCA was carried out on 7 kinds of Satsuma mandarin (*Citrus unshiu* MARC.) trees of which cultivar, tree age and size differed. The cultivars used for the experiments were Otsu No.4 (K3), Sugiyama unshiu (K1 and K6) and Okitsu wase (F1, F2, S9, S16, and S36). The measurement dates were trees number K1, K3 and K6 on April 18th, 2003 and July 23rd, trees number F1 and F2 on December 25th, and trees number S9, S16 and S36 on January 26th, 2004. The measurement by the PCA was carried out in cloudy conditions or around sunset in order to reduce the effect of direct solar radiation. Measurement by the PCA was carried out by the following procedure. First, the intensity of the incident light to the citrus tree was measured at the top of the tree, followed by measurement of the transmitted light of the tree at 30cm intervals (30, 60, 90, 120, 150, 180cm) on 4 azimuths (NE, NW, SE, SW) from the trunk (Fig. 1 A). To the fisheye lens part of the PCA a view cap of 90°which opened in the central direction of the tree was fixed (Fig. 1 B). After the PCA measurement, the following were measured: tree height and tree crown radiuses in 16 or 8 azimuths, whole leaf numbers and average individual leaf area of the all trial trees.

Results and Discussion

The results of total area of leaf, tree crown area, tree height, LAI by PCA, LAItca, leaf area density (LAD) of each tree obtained by the observation are shown in table 1. LAI by PCA was recalculated by 2000-90 support software (LI-COR, inc.) except for the values of the measuring point which was outside the tree crown area. LAItca was obtained by dividing total leaf area by the survey at the tree crown area. LAD was obtained by dividing LAItca at the tree height, which was leaf area per tree crown of m^3.

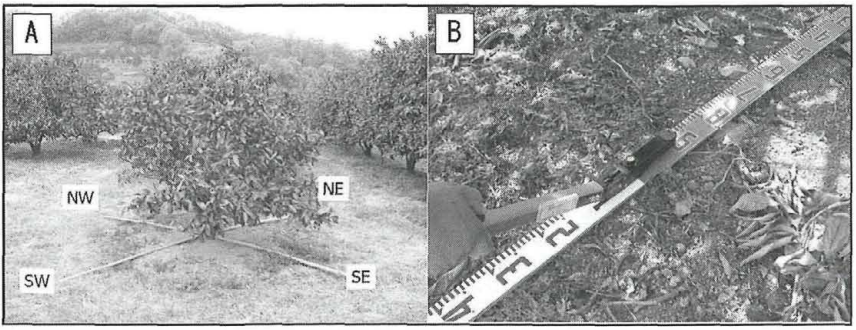

Fig. 1 A: Trial tree and measure location for the PCA measurement. The characters in the figure are azimuths. B: The measurement of the transmitted light of the tree by the PCAwith 90°view cap mounting.

Table 1. Measurement date and calculated value of the each trial tree.

DATE	Apr. 18, 2003			Jul. 23, 2003			Dec. 25, 2004		Jan. 26, 2004		
Tree No.	K1	K3	K6	K1	K3	K6	F1	F2	S9	S16	S36
Total leaf area (m^2)	15.7	9.6	36.4	23.2	18.0	60.5	32.8	43.8	15.4	18.4	71.1
Tree crown area (m^2)	4.1	2.6	14.1	4.6	3.0	15.8	5.9	7.7	5.1	5.4	11.7
Tree height (m)	1.7	1.2	2.5	2.1	1.6	2.8	2.4	2.2	2.2	2.2	3.0
LAI by PCA	2.2	2.1	2.6	2.9	3.4	2.8	3.1	3.1	3.1	3.0	3.9
LAI_{tca}	3.9	3.7	2.6	5.0	6.0	3.8	5.5	5.7	3.0	3.4	6.1
LAD ($m^2 m^{-3}$)	2.3	3.2	1.0	2.4	3.7	1.4	2.3	2.6	1.4	1.5	2.0

The relationship between LAI by PCA and LAItca by the observation is shown in Fig. 2. In the relationship between LAI by PCA and LAItca, there was an underestimation tendency, and a high correlation was not obtained (r = 0.633,

P<0.05). In this study, trees of which cultivar, tree age and size differed were measured in order to examine a measurement procedure that can be adapted to various citruses trees. However, it was considered that this technique can not be applied to all trial trees. Especially, on the trees in which LAD were small, such as trees number K6, S9 and S16, the underestimation tendency of the PCA was smaller than with others. For these trees the proportion of trunk and branch in the tree inside was higher than others. In LAI measurement of the trees by the PCA, it is reported that trunk and branch have also been evaluated as a leaf (NAKANO 2000). And, in the measurement of the PCA in this method, a view cap of 90°, which opened in the central direction of the tree, was used. So, it was considered that the measurement ca be easily affected by the trunk and branches. When the lower LAD trees, such as K6, S9 and S16, were removed, there was an underestimation tendency of about 37%, and a very high correlation (r = 0.959, P<0.01) was obtained. The effect of the size of the trial tree is considered to be cause of the value of LAI by the PCA being underestimated. In the measurement of the PCA, the minimum canopy radius (distance from the sensor location) should generally be at least 3 times the canopy height, and underestimation occurs, when it is smaller than that (LI-COR 1992). The proportion of tree crown radius for the tree height of trees used in this study was from 0.57 to 0.85, and it seemed to be a cause of underestimation. A measuring function for isolated trees is also included in the support software. However, because of the necessity of additional measurements of the size and shape of the tree, adaptation to the production field, which requires a large number of tree measurements, was judged to be difficult.

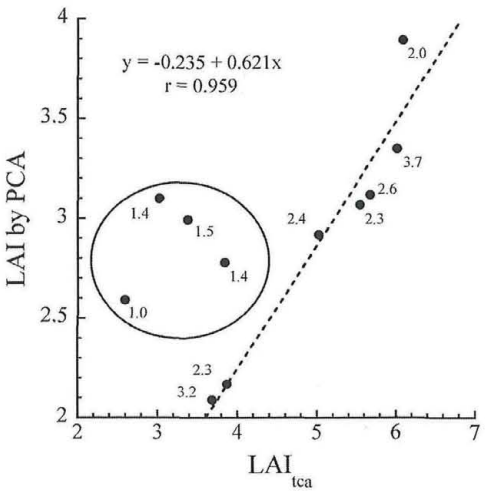

Fig. 2. The relationship between leaf area index (LAI) by PCA and leaf area index per tree crown area (LAItca). Regression formula and correlation coefficient are calculated except for four data in the circle of the solid line. The numerical value near each plot is the leaf area density (LAD: $m^2\ m^{-3}$).

From these results, it was suggested that the possibility of LAI by PCA using this method was an effective index for LAItca in productivity evaluation of citrus trees, except for trees whose proportion of trunk and branch to leaf was high and leaf area density was low.

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