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Effects of Pruning Types on Tree Vigor of Bamboo-Leaf Oak Inferred from Allometric Analysis

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Abstract

There are two well-known types of tree pruning, crown raising and crown reduction. In Japan, the former has been rarely used, whereas the latter has been widely used. However, it remains unclear which type is more effective to maintain tree vigor and health. Bamboo-leaf oak (*Quercus myrsinifolia*) trees were experimentally planted and pruned with the two pruning types compared with the no-pruning type. In the crown raising, the lower part of each tree was pruned, and its dominant leader was maintained from the aspect of structural pruning, whereas in the crown reduction, the upper part of each tree was pruned, and the tree height was reduced. The oak trees were observed and recorded in terms of leaf area, leaf weight, branch weight, and tree shape for about one year. The morphological data were statistically analyzed in terms of their allometric relationships. The crown raising type shared the same allometric patterns with the no-pruning types, but the crown reduction type did not. The trees of the crown reduction type were more likely to suffer from pests and disease. The allometric differences between the two pruning types may be considered the result of a decline in whole-tree vigor and health in crown reduction. The crown raising seemed more likely to control tree vigor and health than the crown reduction. The present results would help arborists determine which method to use for pruning.

Keywords

Allometric Difference, Crown Raising, Crown Reduction, Oak, Tree Growth

1. Introduction

Pruning is a common management practice used to reduce the size of trees. There are two well-known types of tree pruning in urban areas, crown raising and crown reduction [1]. In Japan, the former has been rarely used, whereas the latter has been widely used. The reasons are mainly due to the reduction of vulnerability to damage from strong winds or typhoons the improvement of sunlight distribution around the tree or due to customer requests for crown reduction [2] [3]. However, it remains unclear which type is more effective to maintain tree vigor and health.

Structural pruning is the removal of live branches and stems to influence the orientation, spacing, growth rate, strength of attachment, and ultimate size of branches and stems [4]. Structural pruning should be considered along with raising and performing to maintain a dominant leader [4]. Therefore, the author's previous study [5] hypothesized that crown raising with the maintenance of a dominant leader may help urban trees maintain their vigor and health. The present study aims to experimentally compare the effects of the two pruning types on tree vigor and health, using bamboo-leaf oak (*Quercus myrsinifolia*) trees commonly used as landscape trees in Japan.

Measurements of tree components such as leaf area, leaf weight, and branch weight are considered parameters to represent tree vigor, but they are closely related to each other. Therefore, leaf mass per area (LMA), which is widely used as an indicator of plant functioning such as photosynthetic rates and chemical composition [6], could be also used as a parameter to represent tree vigor.

LMA may be changeable depending on environmental conditions [7] and therefore may be influenced by pruning types. Our previous study showed that the crown reduction caused a decrease in mean LMA [3].

However, LMA consists of two components, leaf density (LD) and the leaf volume-to-area ratio (LVA), and thereby varies depending on these two components in a complicated manner [6]. Therefore, in this study, we perform an allometric analysis of leaf area, leaf weight, and branch weight in a simple manner and thereby estimate differences in tree vigor depending on the crown raising and crown reduction types.

2. Materials and Methods

2.1. Study Site and Trees

The experiment was conducted on 12 trees of *Q. myrsinifolia* from April 2017 to July 2018 in a field in Midori-ku, Sagamihara-shi, Kanagawa-ken, Japan (35˚36'N, 139˚17'E). At the beginning, the 12 six-year-old trees were planted in four rows with three trees 1.8 m apart in each row and a space of 1.8 m between rows. The tree height ranged from 1.9 m to 2.1 m.

2.2. Field Management

All trees were surface-fertilized with cow dung compost (1.7 L/m^2, manufacturer: Tachikawa Heiwa Nouen Co., Ltd., Tochigi-ken, Japan) and chemical fertilizer 8:8:8 (N:P:K, 8 g/m^2, manufacturer: Katakura & Co-op Agri Corporation, Tokyo, Japan) on April 9, 2017, and humus (2 L/m^2, manufacturer: Kanuma Kosan Co., Ltd., Tokyo, Japan) and liquid fertilizer (1 L/m^2 of 100-fold dilution, product name: MOX, manufacturer: Hodogaya Chemical Co., Ltd., Tokyo, Japan) on May 6, and mulch of grass hay.

Irrigation was performed using a bucket three times from the beginning of the experiment to May 21, 2017. After that, only rainfall was used for growing the trees. Mowing was done three times in 2017 and once in 2018.

2.3. Pruning Experiment

The 12 planted trees were equally divided and randomly assigned to the three pruning types depending on different parts of the tree crown pruned: lower part (0 - 0.7 m above the ground), middle part (0.7 - 1.4 m), and upper part (more than 1.4 m). The three types were as follows:

1) Control, where no pruning was conducted.

2) Crown raising, where the upper part was not pruned, but the middle and lower parts were pruned. Pruning severity was the removal of approximately 50% of leaves. This method aimed to maintain a dominant leader (**Figure 1(A)** and **Figure 1(B)**).

3) Crown reduction, where the upper part was almost removed and the middle part was pruned, but the lower part was not pruned. Pruning severity was the removal of approximately 50% of leaves. This method aimed to reduce tree height (**Figure 1(C)** and **Figure 1(D)**).

In 2017, the spring growing season ended, and then the pruning experiment was conducted for the three pruning types from July 5 to 7. Pruning was performed according to standard techniques for urban trees, reduction cut and removal cut [8].

In this experiment, photographs of trees damaged by insects were also taken for consideration in the future management of urban trees.

Figure 1. *Quercus myrsinifolia* oak tree: (A) before pruning, (B) after pruning by crown raising, (C) before pruning, and (D) after pruning by crown reduction.

2.4. Measurements of Branches and Leaves

All branches and leaves were dried in convection ovens (80˚C, 48 hours, product name: NDO-520W, manufacturer: Tokyo Rikakikai Co. Ltd., Tokyo, Japan) and then their total dry weights were measured with a digital scale (product name: SH-2000, manufacturer: A&D Co. Ltd., Tokyo, Japan). Single-leaf dry weight was measured with an electronic balance (product name: AJ-620, manufacturer: Shinko denshi Co. Ltd.,

Tokyo, Japan). The number of leaves was also counted. Single-leaf area was measured with the leaf scan image analysis software LIA32 ver.0.378 (product name: MFC-6490CN, manufacturer: BROTHER INDUSTRIES, Ltd., Aichi, Japan).

2.5. Data Analysis

All statistical tests and graphics were performed using R version 4.3.0 [9] with the packages mentioned below. We calculated standard major axis (SMA) regression with the smatr package [10] in R version 4.3.0 to examine the allometric relationships between single-leaf area and single-leaf dry weight and between total leaf dry weight and total branch dry weight.

3. Results

Allometric analysis between single-leaf area and single-leaf weight (**Figure 2**) showed that the three SMA regression lines did not differ significantly in slope ($\chi^2 = 0.80$, df = 2, $p = 0.67$), but did differ significantly in elevation ($\chi^2 = 10.26$, df = 2, $p = 0.006$) (**Figure 1**). As a result, the three allometric lines were found to be parallel and share a common slope of 1.17. There was a significant difference in elevation between the control and the crown reduction ($p = 0.023$), but not between the control and the crown raising ($p = 0.986$).

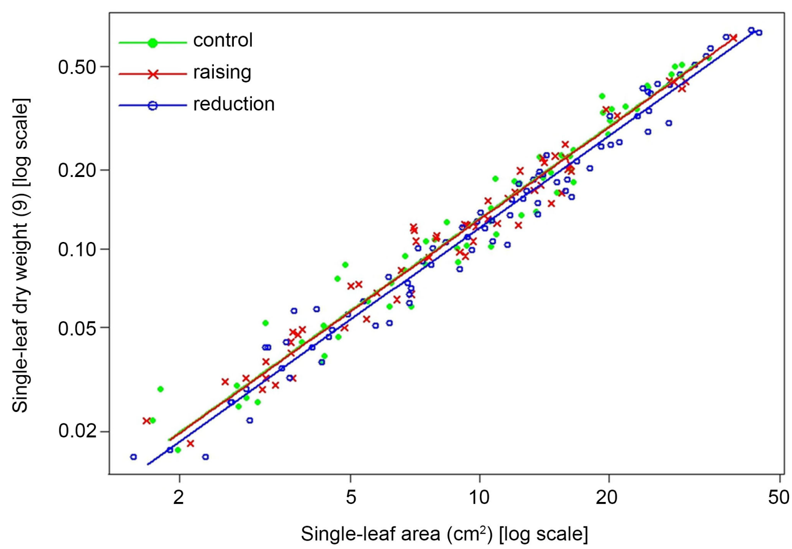

Figure 2. Allometric relationships between single-leaf area and single-leaf dry weight in the three pruning types, control, raising and reduction.

Allometric analysis between total leaf weight and total branch weight (**Figure 3**) showed that the three SMA regression lines did not differ significantly in slope ($\chi^2 = 3.21$, df = 2, $p = 0.20$), but did differ almost significantly in elevation ($\chi^2 = 5.31$, df = 2, $p = 0.07$) (**Figure 2**). As a result, the three allometric lines were found to be parallel and share a common slope of 1.62. There was an almost significant difference in elevation between the control and the crown reduction ($p = 0.063$), but not between the control and the crown raising ($p = 0.999$).

Regarding insect pests, three of the four trees were found damaged by insects (**Table 1**, **Figure 4**). *Oxycetonia jucunda* is well-known as a flower-visiting beetle. However, in this experiment, one adult (sex unknown) of this species was observed staying on a leaf for more than one day (**Figure 4(B)**). Later, the present author experimentally confirmed that an adult female of this species stayed on a leaf of *Quercus myrsinifolia* for more than one day and bored a hole in it in a plastic container (**Figure 5**).

Regarding diseases, in three of the four trees pruned by the crown reduction type, the apical part of new leaves withered and turned dark brown (**Figure 6(A)**), compared to healthy leaves (**Figure 6(B)**).

Table 1. List of insects damaging trees.

Tree ID	Pruning types	Insects	Numbers of individuals
1	Crown reduction	*Monema flavescens* larvae	>50
2	Crown reduction	*Oxycetonia jucunda*	1
2	Crown reduction	*Agrypnus binodulus*	3
3	Crown reduction	*Psychidae* sp. larvae	1

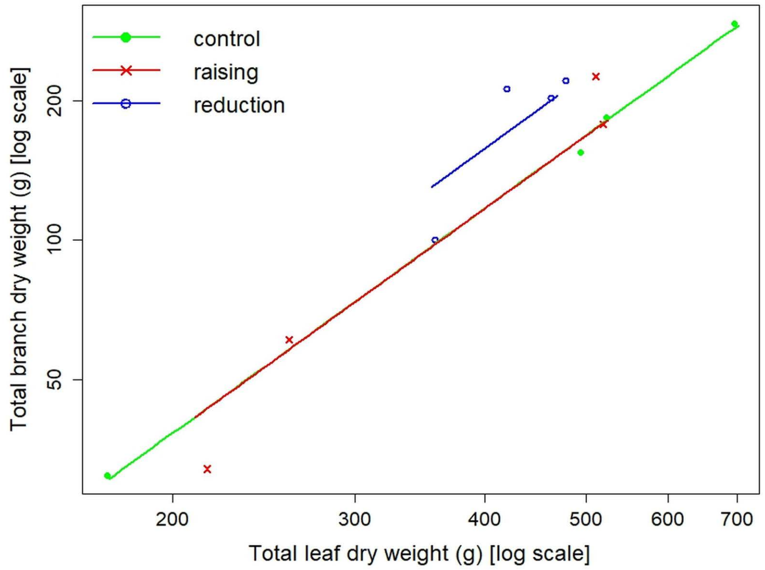

Figure 3. Allometric relationships between total leaf dry weight and total branch dry weight in the three pruning types, control, raising and reduction.

Figure 4. Pest insects found in this study: (A) *Monema flavescens* larvae, (B) *Oxycetonia jucunda*, (C) *Agrypnus binodulus*, and (D) *Psychidae* sp. larvae.

Figure 5. (A) Adult female of *Oxycetonia jucunda* (body length 11 mm) boring a hole in a leaf of *Quercus myrsinifolia*. The red circle refers to the hole in the next figure. (B) The hole of diameter approximately 1 mm shown by the red circle.

Figure 6. Conditions of leaves: (A) diseased leaves and (B) healthy leaves.

4. Discussion

It is notable that the crown raising type shared the same allometric patterns with the control (no-pruning) type both between single-leaf area and single-leaf dry weight and between total branch dry weight and total leaf dry weight, whereas the crown reduction type did not share either allometric pattern with the control type.

The allometry between single-leaf area and single-leaf dry weight showed that the rate of increase in log single-leaf dry weight with respect to log single-leaf area was not significantly influenced by the difference in the pruning types. Furthermore, single-leaf dry weight was less in the crown reduction type than in the crown raising type at any given single-leaf area. These findings suggest that the crown reduction type may cause the density of leaves to be generally lower than the crown raising type [6]. Such a decrease in the density of leaves may have caused a decrease in leaf resistance to pest insects [7]. As a result, the trees of the crown reduction type seemed more likely to suffer from pest insects. At present little information on pest attacks caused by differences in pruning methods is available. Therefore, it is important to collect such information and share it with arborists in future research.

On the other hand, the allometry between total branch dry weight and total leaf dry weight showed that the crown reduction type produced more total branch dry weight than the crown raising type when compared to the control at any given total leaf dry weight. The upward shift in the allometry in the crown reduction type may have reflected branch growth compensating for biomass lost. Such pruning-induced changes in mass and shape may have consequently caused a decline in whole-tree vigor leading to various pest attacks. This inference may be supported by the findings of [3] that the increase in trunk circumference at breast height was suppressed and root rot occurred in trees pruned by the crown reduction type. However, further investigation with a larger sample size is required to confirm this inference.

One of the limitations of this study is that the effect of the severity of pruning on trees was not taken into consideration. Previous studies showed that the severity of pruning affects the growth of trees [11] [12] [13]. Therefore, in future studies, it will be necessary to compare crown raising and crown reduction in various severity of pruning.

5. Conclusion

This study experimentally compared two pruning types, crown raising and crown reduction, in terms of controlling tree vigor in bamboo-leaf oak (*Quercus myrsinifolia*). The results statistically revealed the differences between the two pruning types in allometric relationships between leaf area and leaf weight and between leaf weight and branch weight. These allometric differences may have reflected differences in the vigor of tree growth that resulted from the two pruning types. The crown raising to maintain a dominant leader seemed more likely to control tree vigor than the crown reduction to reduce tree height. Therefore, the present results would help arborists determine which method to use for pruning.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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