Effects of Different Leaf Area Index on Fruit Quality and production of Huangguogan

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Abstract. In this experiment, Citrus Huangguogan was used as the test material, and 5 leaf area index (LAI) treatments were set. The fruit quality and production of each treatment were measured and analyzed. With the decrease of LAI, single fruit weight, horizontal diameter, vertical diameter, total soluble solids, content of total sugar and sugar-acid ratio increased. Meanwhile, fruit shape index and content of Vc didn’t differ significantly, and content of TA decreased significantly. The yield per mu increased first and then descend, simultaneously, the number of fruits per plant, and the yield per plant increased. T1 (2.0) was the appropriate LAI of Huangguogan, under which the yield was higher and the fruit quality was the best.

1. Introduction
Leaf area index (LAI), namely the ratio of the sum of plant leaf surface areas to the land surfaces area [1], is a characteristic parameter that quantitatively describes the spatial distribution and density changes of leaves at the population level [2]. LAI is affected by plant size, age, plant spacing and other factors [3]. LAI can directly affect the plant groups on the capture and use of light energy [4], absorption and transpiration of moisture [5], and transitivity of heat [6]. Furthermore, it has a positive influence on the growth and development of the population [7], photosynthesis [8], transpiration [9] and other physiological processes. It’s also an important indicator of crop yields, vegetation canopy structure and growth health [10]. Its size is of great significance to agricultural production.

LAI of citrus trees of the same age is mainly affected by planting density and degree of trim. At present, there are many studies on the effect of planting density of plants [11], but the planting density cannot completely describe the canopy state quantitatively, which ignores the effect of pruning. Therefore, studying the effect of LAI on plants is more comprehensive and accurate. In this experiment, ‘Huangguogan’ was used as the test material, and we set 5 LAI treatments: 2.0, 2.4, 2.8, 3.2 and 3.6. The fruit quality and yield indexes of each treatment were measured and analyzed for screening out the LAI suitable for Huangguogan. It is of great significance to ensure the high photosynthetic efficiency of Huangguogan, and can provide theoretical basis for the selection of LAI of other citrus varieties.
2. Materials and Methods

2.1 Experimental materials
Experimental land is in Shimian, Sichuan, China. The 7-year-old Huangguogan trees with same canopy and without pests and diseases are used as materials.

2.2 Experimental design
According to the differences in LAI, we set following 5 treatments: 2.0, 2.4, 2.8, 3.2 and 3.6. The setting of LAI was realized by adjusting the planting density and pruning level. Each treatment was pruned once in summer and once in winter, so that the annual LAI change was stable between plus or minus 0.1. LAI was determined by lai-2200 plant canopy analyser [12]. The area of the plot is 0.1 Ha, repeated for 3 times, and the plot interval is more than 10m. The field management of all treatments except pruning was consistent.

2.3 Test methods

2.3.1 Fruit quality measurement method. Vernier calipers were used to measure the vertical and horizontal diameters of fruits and calculate the fruit shape index. The single fruit weight was measured by AL204 electronic balance. The content of total soluble solids (TSS) was determined by TD-45 digital sugar meter. Total sugar content was determined by anthrone-colorimetry. Acid base neutralization titration method was used to determine titratable acid (TA) content. The content of Vc was determined by molybdenum blue colorimetry [13].

2.3.2 Production measurement method. Harvest the test plants individually, record the number of fruits and yield per plant and calculate the yield per mu.

3. Results and analysis

3.1 Effect of LAI on external quality of Huangguogan
The single fruit weight, horizontal diameter and vertical diameter of Huangguogan under different LAI treatments were significantly different, meanwhile the difference in fruit shape index was not significant, which was maintained between 0.97 and 1.04, as shown in Tab.1. The single fruit weight of T1 was 231.6g, which was 37.6% higher than that of T5. The horizontal and vertical diameters of T1 were 8.15 and 7.89 cm, respectively, which were 19.50% and 10.81% higher than those of T5. The result indicated that low LAI conditions were more conducive to growth and development of Huangguogan fruits.

| Treatment | Fruit weight /g | Horizontal diameter /cm | Vertical diameter /cm | Fruit shape index |
|-----------|-----------------|-------------------------|-----------------------|-------------------|
| T1        | 231.6 ± 4.9 a   | 8.15 ± 0.18 a           | 7.89 ± 0.16 a         | 0.97 ± 0.03 a     |
| T2        | 212.4 ± 4.5 b   | 7.80 ± 0.13 ab          | 7.83 ± 0.14 a         | 1.00 ± 0.03 a     |
| T3        | 207.2 ± 2.9 b   | 7.54 ± 0.17 bc          | 7.49 ± 0.12 b         | 0.99 ± 0.01 a     |
| T4        | 178.3 ± 4.1 c   | 7.11 ± 0.18 cd          | 7.19 ± 0.06 c         | 1.01 ± 0.03 a     |
| T5        | 168.3 ± 7.0 d   | 6.82 ± 0.20 d           | 7.12 ± 0.08 c         | 1.04 ± 0.02 a     |

3.2 Effect of LAI on inner quality of Huangguogan
Table 2 shows that TSS, total sugar content and sugar-acid ratio increased with the decrease of LAI. Those were higher both in T1 and T2, and those three indexes of T1 were 22.67%, 16.89% and 36.05%
higher than T5, respectively. There was no significant difference in Vc content among treatments. TA significantly decreased with LAI reduction, and TA in T1 was the lowest, only 0.73 g/100mL, which was 16.44% lower than that in T5.

### Tab 2. Fruit inner quality of Huangguogan with different LAI

| Treatment | Total soluble solids /% | Vc content /mg·ml⁻¹ | Total sugar /g·100ml⁻¹ | Titratable acid /g·100ml⁻¹ | Ratio of Sugar and acid |
|-----------|-------------------------|----------------------|------------------------|-----------------------------|-----------------------|
| T1        | 12.23 ± 0.15 a          | 32.63 ± 0.51 a       | 8.79 ± 0.19 a          | 0.73 ± 0.10 c               | 12.04 ± 0.09 a        |
| T2        | 11.87 ± 0.15 a          | 32.91 ± 1.03 a       | 8.27 ± 0.16 b          | 0.79 ± 0.07 ab              | 10.46 ± 0.21 b        |
| T3        | 11.34 ± 0.34 ab         | 32.29 ± 0.91 a       | 8.16 ± 0.15 b          | 0.78 ± 0.09 ab              | 10.46 ± 0.22 b        |
| T4        | 10.47 ± 0.61 bc         | 32.73 ± 0.87 a       | 7.96 ± 0.22 bc         | 0.83 ± 0.09 a               | 9.59 ± 0.13 c         |
| T5        | 9.97 ± 0.50 c           | 33.35 ± 0.99 a       | 7.52 ± 0.10 c          | 0.85 ± 0.07 a               | 8.85 ± 0.27 d         |

Note: Values within a column followed by different lowercase letters indicate the significant difference (P<0.05), and the same as below.

3.3 Effect of LAI on production of Huangguogan

With the enhancement of LAI, the number of fruits and yield per plant of Huangguogan decreased significantly, as shown in Table 3. The number of fruits per plant of T1 was significantly higher than that of other treatments, reaching 358. The yield per plant of T1 showed the same pattern, up to 102.0kg/plant, which was 3.5 times that of T5. The result indicated that the growth quality and biomass accumulation of single plant of Huangguogan were better when the LAI was lower.

### Tab 3. Production of Huangguogan with different LAI

| Treatment | Fruit number / per tree | Yield per plant /Kg | Yield per mu /Kg |
|-----------|-------------------------|---------------------|------------------|
| T1        | 358 ± 29 a              | 102.0 ± 8.4 a       | 3 367.0 ± 177.1 bc |
| T2        | 321 ± 12 b              | 71.9 ± 2.7 c        | 3 954.7 ± 149.4 ab |
| T3        | 312 ± 10 b              | 64.0 ± 2.0 c        | 4 029.5 ± 125.4 a |
| T4        | 275 ± 10 c              | 50.1 ± 1.9 d        | 3 703.7 ± 140.6 abc |
| T5        | 173 ± 10 d              | 28.9 ± 1.7 e        | 3 206.9 ± 192.7 c  |

4. Discussion and conclusion

LAI can directly affect the interception and utilization of light energy by plant populations, thus affecting the growth and development of plants [14], and ultimately leading to differences in fruit quality and yield. Ciampitti’s Research[15] shows that the reduction of LAI is beneficial to improve photosynthesis, promote the accumulation of dry matter, and help the increase of yields. However, this study found that the yield of per mu rose first and then declined due to the increase in LAI, indicating that LAI only affects the yield of Huangguogan in a certain range.

When LAI reduced, resource competition among plants was weakened, leading to a significant increase in the single fruit weight, horizontal diameter, vertical diameter, TSS, total sugar and sugar-acid ratio, and a significant decrease in titratable acid content. It may be that, when LAI decreased, the degree of mutual shelter between leaves in the canopy decreased, the photosynthetic capacity of leaves increased. The results showed that the photosynthetic capacity of leaves increased, the dry matter accumulation increased, and the fruit quality increased as a whole. The results are similar to those of Huang [16] on cherry.
In conclusion, the decrease of LAI is conducive to the improvement of photosynthesis and fruit quality of Huangguogan. Under LAI=2.0, the yield was higher and fruit quality was the best, which was the appropriate LAI of Huangguogan.

References
[1] Watson D J. (1947) Comparative Physiological Studies on the Growth of Field Crops: I. Variation in Net Assimilation Rate and Leaf Area between Species and Varieties, and within and between Years[J]. Annals of Botany, 11(41):41 - 76.
[2] Chen J M, Black T A. (1992) Defining leaf area index for non-flat leaves[J]. Plant, Cell & Environment, 15(4): 421 - 429.
[3] Watson D J. (1952) The Physiological Basis of Variation in Yield[J]. Advances in Agronomy, 4(4): 101 - 145.
[4] Kalttorres W, Kerr P S, Usuda H, et al. (1987) Diurnal changes in maize leaf photosynthesis: I. Carbon exchange rate, assimilate export rate, and enzyme activities.[J]. Plant Physiology, 83(2): 283 - 288.
[5] Wang Y, Tian Q, Wang Q, et al. (2016) The appicability of leaf area index estimation model in an aspen forest over a growth period[J]. Acta EcologicaSinica, 36(8).
[6] Wang C Y, Guo X Y, Du J J. (2018) Maize leaf area index continuous monitoring based on time-series infrared images [J]. Transactions of the Chinese Society of Agricultural Engineering, 34(06): 175-181 (In Chinese with English abstract).
[7] Gholz H L. (1982) Environmental Limits on Aboveground Net Primary Production, Leaf Area, and Biomass in Vegetation Zones of the Pacific Northwest[J]. Ecology, 63(2): 469-481.
[8] Maddoni G A, Otegui M E, (2001) Cirilo A G. Plant population density, row spacing and hybrid effects on maize canopy architecture and light attenuation[J]. Field Crops Research, 71(3): 183 - 193.
[9] Lemaire G, Marsden C, Verhoef W, et al. (2011) Leaf area index estimation with MODIS reflectance time series and model inversion during full rotations of eucalyptus plantations[J]. Remote Sensing of Environment, 115(2): 586 - 599.
[10] Xiao Z, Liang S, Jiang B. (2017) Evaluation of four long time-series global leaf area index products[J]. Agricultural & Forest Meteorology, 246: 218 - 230 (In Chinese with English abstract).
[11] Shao Y, Zeng J B, Guo Y P. (2016) Effects of planting methods on chlorophyll, fluorescence and yield of summer maize under high density condition. Agricultural Research In The Arid Areas, 85 – 90 (In Chinese with English abstract).
[12] He K L, Du M W, Tian X, et al. (2015) Effect of Cotton Planting Density on the Estimation of Leaf Area Index Using the LAI-2200 Plant Canopy Analyzer [J], Crops, 123 – 127 (In Chinese with English abstract).
[13] Xiong Q E. (2003) Experimental course in plant physiology [M]. Sichuan science and technology press. (In Chinese with English abstract).
[14] Kalttorres W, Kerr P S, Usuda H, et al. (1987) Diurnal changes in maize leaf photosynthesis: I. Carbon exchange rate, assimilate export rate, and enzyme activities.[J]. Plant Physiology, 83(2): 283 - 288.
[15] Ciampitti LA, Vyn TJ. (2011) A comprehensive study of plant density consequences on nitrogen uptake dynamics of maize plants from vegetative to reproductive stages [J]. Field Crops Research, 121: 2-18.
[16] Huang S P, Ma X L, Zhao D Q, et al. (2017) Effects of planting density on photosynthetic characteristics, yield and fruit quality of sweet cherry [J].South China Fruits, 46(03): 148-151 (In Chinese with English abstract).