Effects of planting density on diurnal variation of microenvironment in Huangguogan orchards

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Abstract: In this experiment, Huangguogan was used as the material. The effects of different planting densities on the diurnal variation of microenvironment in citrus orchard was studied, and the key research findings are as below. The orchard environmental factors, including light, daily average temperature and soil moisture, increased with the decrease of planting density. Compared with the density of 2×3m, the photosynthetically active radiation (PAR in short), air temperature, soil temperature and soil moisture of density 4×5m on average increased by 423.7%, 5.5%, 2.18% and 4.9%. Air CO₂ concentration and air humidity on average decreased by 1.8% and 4%. The daily range of PAR, air temperature, air humidity, soil temperature and soil humidity increased, and the daily range of air CO₂ concentration decreased.

1. Introduction
Citrus is a subfamily aurantiioideae of Rutaceae[1], which is the king of fruits in the world and one of the most important fruit in China[2]. The varieties tested in this study was Huangguogan, a natural hybrid citrus of mandarin and orange[3].

Planting density adjustment is one of the important cultivation techniques in citrus planting. Population density can directly affect the environmental factors within the population, and different density groups will have different microclimate characteristics [4]. When the population density increases, the whole growth environment of the plant changes, including light intensity[5], temperature[6], humidity[7], wind speed[8], CO₂ concentration[9] and other microclimate factors, thus affecting the growth process and final yield of the plant[10].

Therefore, studying the effect of planting density on the diurnal variation of microenvironmental factors in citrus orchards, and selecting suitable planting density for Huangguogan, is important for to ensure its high efficiency and quality, further promoting Huangguogan industry.

2. Materials and Methods

2.1 Materials
Experimental land was in Shimian, Sichuan, China. The 7-year-old Huangguogan trees with same canopy and without pests and diseases were used as materials.
2.2 Experimental Design
According to densities, six density treatments were set up as shown in Table 1. Each plot area was 0.1 ha, repeated 3 times, and the plot interval was more than 10 m. Field management was consistent for each treatment.

Table 1. The list of treatments

| Treatment | Plant spacing × Row spacing |
|-----------|-----------------------------|
| T1        | 2×3m                        |
| T2        | 3×3m                        |
| T3        | 3×3.5m                      |
| T4        | 3×4m                        |
| T5        | 4×4m                        |
| T6        | 4×5m                        |

2.3 Test methods
The experiment was carried on a sunny day from 8:00-18:00 during the fruit developing period of Huangguogan every two hours. PAR and CO₂ concentration were measured using the portable photosynthesis apparatus (LI-6400). Air temperature and humidity were measured with H19565 portable temperature and hygrometer. Soil temperature and humidity were measured using the LTS-EMLOG-TH temperature and humidity recorder system. All indicators were measured 3 times.

3. Results

3.1 Effects of Plant Density on Diurnal Variation of Photosynthetically Active Radiation in Orchard
As shown in Fig.1, the daily changes of PAR in Huangguogan rose first and then fell, reaching the maximum value at 12:00. There were obvious differences among treatments. The daily mean value of PAR expressed as T6 > T4 > T5 > T3 > T2 > T1. The daily range of PAR showed the same rule. It could be seen that PAR obviously increased as the density decreasing, which was beneficial to photosynthesis, but the daily change was relatively drastic.

![Figure 1. Diurnal variation of PAR in Huangguogan orchard with different densities](image)

3.2 Effects of Plant Density on Diurnal Variation of CO₂ in Orchard
As shown in Fig.2, the daily change of CO₂ concentration in the orchard showed a downward trend initially, and then showed an upward trend, in which kept at a low level during the period from 10:00 to 14:00. The daily mean value of CO₂ concentration expressed as T6 < T5 < T4 < T3 < T2 < T1. The daily range of CO₂ concentration showed the same rule, and it in T1 was 3.1 times higher than T6. It can be seen that the daily change of CO₂ concentration was opposite to the change of PAR.
Figure 2. Diurnal variation of CO₂ in Huangguogan orchard with different densities

### 3.3 Effects of Plant Density on Diurnal Variation of air temperature and humidity in Orchard

The changes of air temperature and humidity in orchards of different densities showed an opposite regulation as shown in Fig.3. The air temperature in orchards rose first and then decreased, with a peak at about 14:00. The trend of air humidity was the opposite. The changes of air temperature and humidity in low-density were more rapidly and intensely than that in high-density orchards, which determined by slow external heat exchange. Under this circumstance, the denser branches and leaves of high-density orchards, with severe occlusion between leaves and poor air permeability. Therefore, the air temperature rose slowly and the daily changes of air temperature and humidity in high-density orchards were relatively small.

Fig.3 Diurnal variation of air temperature and humidity in Huangguogan orchard with different densities

3-A: Diurnal variation of air temperature, 3-B: Diurnal variation of air humidity.

### 3.4 Effects of Plant Density on Diurnal Variation of soil temperature and humidity in Orchards

The changes of soil temperature and humidity in Huangguogan orchards lagged behind the changes of those in air. The changes of soil temperature and humidity both showed a descending-ascending-descending trend. The daily difference of soil temperature showed as T₆ > T₄ > T₅ > T₃ > T₂ > T₁. The change of soil temperature in low-density orchards was more drastic than that in high-density orchards. Soil humidity is an important indicator of fruit tree growth. The daily mean value of soil humidity appeared as T₆ > T₄ > T₅ > T₃ > T₂ > T₁. With the increase of density, soil humidity decreased gradually, and water contention increased, which may be detrimental to the growth of fruit trees.
Fig. 4 Diurnal variation of soil temperature and humidity in Huangguogan orchards with different densities

4-A: Diurnal variation of soil temperature, 4-B: Diurnal variation of soil humidity.

4. Conclusions

Light is the most important environment factor affecting photosynthesis [11]. With the decrease of density, the ventilation and light transmittance in the canopy were improved. With the increase of density, mutual shading was more serious, and PAR of population decreased significantly, causing the canopy to overhang as in T1. On the other hand, as the density decreased, the PAR in the canopy of the tree was obviously improved. The results were consistent with those of Ma [12].

The diurnal variation of CO₂ concentration in each treatment group was more complex than PAR, which was similar to the research of Liu [10]. In the morning and evening, the CO₂ consumed by photosynthesis was less than that released due to the weak light intensity. The overall respiration rate of high-density treatment was higher, so the CO₂ concentration was higher than that of low-density treatment. After 10:00, with the increase of light intensity and the enhancement of photosynthesis, a large amount of CO₂ was consumed in the population and the concentration dropped rapidly. However, the low-density treatment had a larger row spacing and better ventilation condition. When CO₂ was consumed in the population, the external CO₂ could be timely replenished, so that the CO₂ concentration in the low-density treatment wouldn’t fall rapidly.

Temperature and humidity are also important factors, having important effects on physiological process [13]. This study found that the air and soil temperature in the canopy were similar, and the daily mean value increased with the decrease of density. Appropriate temperature could activate photosynthetase and photosystem [9], while the average daily temperature of low-density Huangguogan orchard was higher, which was more conducive to improve photosynthesis capacity. Soil and air humidity can directly change the moisture status, and affect photosynthesis indirectly [11]. The study found that soil humidity increased significantly with the decrease of density. With the decrease of density, the water competition gradually weakened, and the soil humidity increased by 22.23%. It can be seen that the moderate reduction of planting density was beneficial to the soil water retention of citrus orchard.

In conclusion, the decrease of density was beneficial to the micro-environment of the orchard, as well as the photosynthetic capacity and fruit quality of Huangguogan.

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