Research on spatial distribution of photosynthetic characteristics of Winter Wheat

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Abstract. In order to explore the spatial distribution of photosynthetic characteristics of winter wheat leaf, the photosynthetic rate on different parts of leaf (leaf base-leaf middle-leaf apex) and that on each canopy (top layer-middle layer-bottom layer) leaf during the whole growth period of winter wheat were measured. The variation of photosynthetic rate with PAR and the spatial distribution of winter wheat leaf during the whole growth periods were analysed. The results showed that the photosynthetic rate of different parts of winter wheat increased with the increase of PAR, which was showed as leaf base>leaf middle>leaf apex. In the same growth period, photosynthetic rate in different parts of the tablet was showed as leaf middle>leaf base>leaf apex. For the different canopy layer of winter wheat, the photosynthetic rate of the top layer leaf was significantly greater than that of the middle layer and lower layer leaf. The photosynthetic rate of the top layer leaf was the largest in the leaf base position. The photosynthetic rate of leaf of the same canopy layer at different growth stages were showed as tasseling stage > grain filling stage > maturation stage.

1. Introduction

Winter wheat was one of the most important grain crops in China, and its annual output played a key role in the stability of population grain in China. Photosynthesis of winter wheat leaves directly affected the grain yield and productivity[1], and the formation of population productivity was affected by canopy distribution[2]. Therefore, it was of great significance to study the photosynthetic characteristics of winter wheat in order to improve its yield. PAR was one of the most important environmental factors affected the photosynthetic characteristics of winter wheat[3-4]. Photosynthetic rate of leaf at different parts and canopy position has different response to photosynthetic active radiation. During tasseling stage, vegetative growth gradually shifted to reproductive growth. Physiological activity was very vigorous, and it was more sensitive to photosynthetic radiation. During the grain filling stage, leaves began to senescence, and photosynthate in winter wheat began to transfer[5-7].

From the current researched progress, the influence of the winter wheat species [8-9] and the water consumption [10-13] on the photosynthetic rate have been studied more. But the research on spatial
distribution of photosynthetic rate at different parts of winter wheat leaves, at different leaf positions and at different growth stages were less. Therefore, the research on spatial distribution characteristics of leaf photosynthetic rate on winter wheat different growth period in North China was researched. It can provide a theoretical basis for the high yield of winter wheat in this region.

2. Test Design and layout

2.1 Experiment site
Field experiments were carried out from October 2016 to June 2017 at Daxing experimental base of national water saving irrigation engineering technology research center (Beijing) (39°37.25′N, 116°25.51′E). The station is located in the North China Plain, with semi-arid continental monsoon climate, the annual average frost free period of 185 days, annual average evaporation in more than 1800mm. The annual sunshine duration was about 2600h. The light and heat conditions are very abundant.

2.2 Irrigation design
During the whole growth period, winter wheat was irrigated three times with a total of 180mm. The irrigation water in overwintering stage was 60mm, and 60mm in shooting stage and tasseling stage, respectively. The measurement were taken from April 27th to May 5th in tasseling stage, from May 10th to May 17th in grain filling stage and from May 20th to May 28th in maturation stage.

2.3 Measurements
The photosynthetic rate (Pn) of winter wheat (Jingdong 22) was measured by portable Li-6400 photosynthetic apparatus produced by the LI-COR company (USA) from April 23th to June 8th, 2017. At the same time, ten light intensity gradients were set with an external red and blue light source, and the light response curves were measured by 2500, 2000, 1500, 1000, 500, 200, 100, 50, 20, 0 μmol m⁻²s⁻¹, respectively.

The winter wheat canopy was divided into three layers (top layer, middle layer and bottom layer) at the vertical height. Three positions were measured for each leaf at every leaf. They are leaf base, leaf middle and leaf apex, respectively. The measurements were taken from 8:00 to 17:00 in the sunny day. The plants grew well with no pests were selected. The sunshine leaves could be fully accepted. As far as possible, the spatial orientation, inclination and character of each selected leaf were similar, so as to reduce the error between measurement.

3. Results

3.1 Light response on different parts of leaf

![Fig.1 Response of photosynthetic rate on different parts of winter wheat leaf to PAR](image)

As shown in Fig.1, the photosynthetic rate at different parts of the same canopy increased with the increased PAR, which was expressed as leaf base>leaf middle>leaf apex. When PAR was greater than
1600 μmol mol\(^{-1}\), the photosynthetic rate at different parts of winter wheat leaf decreased slightly, which might have been due to the existence of a light saturation point of winter wheat leaf when PAR reached 1600 μmol mol\(^{-1}\).

On the whole, photosynthetic rate reached the maximum at the leaf base of the top layer leaf, and the maximum value was 23.3 μmol m\(^{-2}\)s\(^{-1}\). The photosynthetic rate of the middle and bottom layer leaf was smaller and the minimum value was 4.9 μmol m\(^{-2}\)s\(^{-1}\). This was because the leaf apex in the grain filling stage became yellow, and the chlorophyll of photosynthesis could be less. According to Fig.1(c), when PAR was greater than 1500 μmol mol\(^{-1}\), the photosynthetic rate of leaf base was smaller than that of leaf middle, because the leaf base was connected with stems. At the late growth stage, the rate of water migration was slowed, which affected the photosynthesis of leaf.

### 3.2 Light response of leaf at different leaf positions

![Fig.2 Response of photosynthetic rate of leaf in different canopy of winter wheat to PAR](image)

**Fig.2** Response of photosynthetic rate of leaf in different canopy of winter wheat to PAR 

(a) leaf base, (b) leaf middle, (c) leaf apex

Fig.2 was the response of photosynthetic rate to PAR in different canopy of winter wheat. From Fig.2, we could find that the photosynthetic rate of the leaf at different leaf positions of winter wheat increased with the increase of PAR. For the leaf base, leaf middle and leaf apex, the photosynthetic rate of the top layer leaf was obviously greater than that of the middle and bottom layer leaf. The photosynthetic rate of leaf base at top layer leaf reached the maximum, and the maximum value was 23.8 μmol m\(^{-2}\)s\(^{-1}\). The photosynthetic rate of leaf apex at bottom layer leaf was the smallest, and the minimum value was 4.9 μmol m\(^{-2}\)s\(^{-1}\). That was due to the different interception of light energy in the canopy. Top layer leaf intercepted more sunlight with best physiological activity. The water content of top layer leaf was higher, which lead to the process of promoting photosynthesis better.

### 3.3 Light response of leaf at different growth stage in different canopy layer

![Fig.3 Response of photosynthetic rate to PAR in different canopy of winter wheat at different growth stage](image)

**Fig.3** Response of photosynthetic rate to PAR in different canopy of winter wheat at different growth stage

(a) top layer, (b) middle layer, (c) bottom layer

Fig.3 was the response of leaf photosynthetic rate to PAR at different growth stages in the same canopy of winter wheat, which was expressed as tasseling stage > grain filling stage > maturation stage. The photosynthetic rate of the top layer leaf and middle layer leaf were greater than that of the bottom
layer leaf at the same growth period.

As showed in Fig.3, the photosynthetic rate of the top layer leaf reached the maximum in the tasseling stage of winter wheat, and the maximum value was 15.3 μmol m⁻²s⁻¹. The rising of the temperature promoted the rapid growth of winter wheat with the increasing of leaf area index in the whole growth period. There was no obvious change in photosynthetic rate of winter wheat leaf at the filling stage. For middle layer leaf, the photosynthetic rate at tasseling stage was obviously greater than that of the other two growth periods. It was because the leaf of winter wheat was newly developed leaf at the tasseling stage, and received more sunlight. It was beneficial to the production and accumulation of photosynthetic materials, and to promote photosynthesis and to increase photosynthetic rate of leaf. The overall photosynthetic rate of the leaf at bottom layer became smaller because of the early drought wilting and poor living power, and the photosynthetic rate is only 5.1 μmol.m⁻²s⁻¹ at maturation stage.

3.4 Light response of leaf at different growth stage

![Fig.4](image)

**Fig.4** Response of photosynthetic rate to PAR in different parts of wheat leaf at different growth stages (a) leaf base, (b) leaf middle, (c) leaf apex

Fig.4 showed the response of photosynthetic rate to PAR at different growth stages of Winter Wheat. The photosynthetic rate in the early growth stage was greater than that of the late growth stage. For the same growth period, the photosynthetic rates in different canopy was expressed as leaf middle > leaf base > leaf apex.

For the leaf base and the leaf apex, there was little difference in photosynthetic rate between tasseling stage and grain filling stage, but it was significantly higher than that of maturation stage. For the leaf apex, the photosynthetic rate of leaf at the maturation stage was the lowest, and the minimum value was 4.2 μmol.m⁻²s⁻¹. In the middle layer leaf, the changes in leaf photosynthetic rate of three different growth stages were expressed as tasseling stage > grain filling stage > maturation stage.

4. Conclusion

(1) For the same canopy layer of winter wheat, the photosynthetic rate at different parts of leaf increased with increased PAR, which were expressed as leaf base > leaf middle > leaf apex. The photosynthetic rate at the early growth stage was greater than that of the late growth stage for the same position of leaf. For the same growth period, the photosynthetic rate of different parts of leaf was expressed as leaf middle > leaf base > leaf apex.

(2) The photosynthetic rate of top layer leaf was significantly greater than that of the middle and lower layer leaf, and the photosynthetic rate of the top layer leaf reached the maximum in the leaf base position. For the same canopy layer leaf, the photosynthetic rate at different growth stages were expressed as tasseling stage > grain filling stage > maturation stage.

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