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Effects of source reduction on photosynthetic rate, dry mass and distribution in pumpkin

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ABSTRACT

The four treatments were designed for studying the effects of source reduction by removing leaves on photosynthetic rate, dry mass and distribution in pumpkin, including that the source was reduced to 25% (T1), to 50% (T2), to 75% (T3), and CK. The results showed that when the source reduced to 25%, the photosynthetic rate of leaves behind fruit dropped first, followed by the fruit leaves and leaves in front of fruit. In contrast, the photosynthetic rate remained the same when the source reduced to 75%. Under cloudy weather condition, the photosynthetic rate showed the same variation trend with light radiation, including a unimodal curve with the peak between 14:00–16:00 PM. On the sunny day, the photosynthetic rate showed a single peak curve while the photosynthetic rate showed a bimodal curve. Whenever in the cloudy or sunny day, the photosynthetic rate in T3 was significantly higher than other treatments; however, there was no significant difference on photosynthetic rate between T2 and CK. When the source reduced to 75%, the total dry mass increased 18.66%, while it decreased 36.25% when reduced to 25%. With more reduction of the source, the flux of photosynthetic products to the sink became more efficient. Therefore, during the flowering and early fruit development stage in pumpkin, appropriate source reduction by removing some leaves on vine not only maintained the photosynthetic rate, but also improved the flux from source to sink, thereby increasing the accumulation of total dry mass and yield.

1. Introduction

Pumpkin (*C. moschata*) that is drought-resistant and suitable for low seedling density cultivation becomes the preferred economic crop for semi-arid regions in North-west of Hebei province in China. However, in these areas, for pumpkin cultivation, the second or third female flower on main vine are usually kept while only one or two leaves are kept in front of each fruit and the remaining secondary vines are removed, which results into the formation of one fruit with more than a dozen leaves in a single vine. Whether this source:sink ratio is appropriate still remains unclear. If the source is bigger and the sink smaller, then the water transpiration loss is more by source (leaf); hence, the formation of the production will be affected. Therefore, it is of great significance for guiding local pumpkin production, conservation of water resource to determine the appropriate source:sink ratio.

Extensive studies had been conducted to study the source–sink relations in cotton, peanuts, corn, rice and fruit trees [1–7]. Studies had found that the adjustment of the source:sink ratio could change the photosynthetic characteristics and dry matter accumulation and allocation, reduce the capacity of the sink, and decrease the photosynthetic rate [8,9]. After the source was reduced, the source leaf photosynthetic performance could be compensated [9], and canopy photosynthetic rate decreased [10]. When the source was reduced 1/2 or 3/4, corn yields were reduced [11]. In wheat, the source reduction reduced dry mass production, and reduced its allocation to the grains while the sink reduction had very little effect on mass production [12]. However, in the semi-arid regions in North-west of Hebei province with short frost-free period, the effects of source reduction in pumpkin on photosynthetic characteristics and dry matter accumulation and distribution have not been studied to date. In this study, using "Jingpinxiangli" pumpkin, the effects of different levels of source reduction on photosynthetic rate and plant dry matter accumulation and distribution could be studied to determine the suitable source:sink ratio for pumpkin, providing guidance for large-scale pumpkin production and higher water use efficiency in this area.

2. Materials and methods

2.1. Experimental materials

Experiments had been conducted during 2012 and 2013 at the Zhangbei Agricultural Resource and Ecological Environment Key Field

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Research Station, Hebei Province, China (41°11.35′N, 114°51.20′E). This area has an altitude of 1450 m, the annual mean temperature of 2.7 °C, annual average sunshine hours of 2600 h, annual precipitation of 393 mm. Evaporation per year is 1695 mm, and dry index is 2.0, which is arid and barren land. On average, the frost-free period is 90–110 days [13]. The soil is sandy chestnut soil, with 113.5 mm maximum effective water holding capacity for 0~100 cm soil, 0.82% organic matter content between 0 and 20 cm soil and the pH value of 7.42 [14]. The pumpkin cultivar is "Jingpinxiangli".

2.2. Experimental design

Pumpkin seeds were germinated in greenhouse on May 13, and planted on June 3 with two leaves. Base fertilizer was applied to the soil before planting with 60 kg/ha nitrogen, 45 kg/ha P_2O_5, urea (including 46% nitrogen), and diammonium phosphate (containing 46% P_2O_5 and 18% nitrogen). Base fertilizer was only applied into the pumpkin planting rows. Pumpkin plants were planted on the furrow that is at the ground level with 40 cm × 150 cm spacing, and the ridge is 7~8 cm high and 60 cm wide. After planting, the pumpkin plants had the same amount of irrigation (1 kg). After irrigated when pumpkin planted until the harvest, no water was irrigated. The 80 cm wide furrow was covered with plastic film, and plants were released from the plastic film and covered with soil. Total rainfall during pumpkin growth and development stage was 201.6 mm. From May to September, the monthly average temperature is 12.1~19.4 °C, the average maximum temperature is 24.9 °C, the average minimum temperature is 11.0 °C, the diurnal range of 10.7~13.6 °C.

During flowering and fruit setting periods (July 28), pumpkin plants were selected with similar growth rate, same fruit position (No. 8 node), and flowering on the same day. For these plants, only one fruit was kept on main vine. The number of leaves removed for each plant was different from the base to top. For treatment 1 (T1), only leaves in front of, on and behind the fruit (three leaves in total) were kept so that the source was reduced to 25%. For treatment 2 (T2), six leaves were kept and shoot apical meristem was removed, therefore leading to 50% source reduction. For treatment 3 (T3), nine leaves were kept to reduce 25% source. As the control (CK), 12 leaves were kept. All plants only contained a single vine. Each furrow was planted with only one row of pumpkins, at a distance of 1.5 m, which was 6 m long and 2 m wide. A plot covered an area of 6 m × 4 m = 24 m^2. Each treatment had three biological replicates in random order with 30 plants for each replicate.

2.3. Experimental measurements

CI301-PS photosynthesis system (American CID) was used to measure photosynthetic rate between 9:00 and 11:00 AM. Five plants were selected from each plot, and the mean value was calculated. At harvest, five plants were selected from each plot; plant organs were decomposited for weighing dry weight. Dry weight was determined by drying method, including 105 °C treatment for 30 minutes, and then dried at 80 °C to constant weight. To determine leaf area at harvest, 100 different sizes of leaves were imaged with a digital camera, and the length and width of leaves were measured using Photoshop software. Then, the correlation of leaf area with blade length and width is obtained as a function of: $Y = -84.20 + 7.84\ X_1 + 2.93\ X_2$, $p = 0.0000$, Y is the leaf area; X_1 and X_2 denote leaf length and width. The leaf area capacity (g/m^2) = dry weight of reproductive organ (g)/leaf area (m^2); five plants were selected from each plot, each treatment has total 15 plants for calculating the amount of leaf area load, and the mean value was calculated. Since the data from 2012 and 2013 are similar, only the data from 2013 were present here. The data were analysis by Microsoft Excel 2003 and DPS processing system.

3. Results

3.1. Effects of source reduction on photosynthetic rate in pumpkin

With source reduction, the photosynthetic rate in pumpkin increased first and then decreased, but the time for photosynthetic rate of leaves at different positions to reach the highest value is different (Fig. 1). The photosynthetic rate reached the highest for plants in T1 at early fruit development period (August 9) while the leaves in front of or on fruit of plants in other treatments have the highest

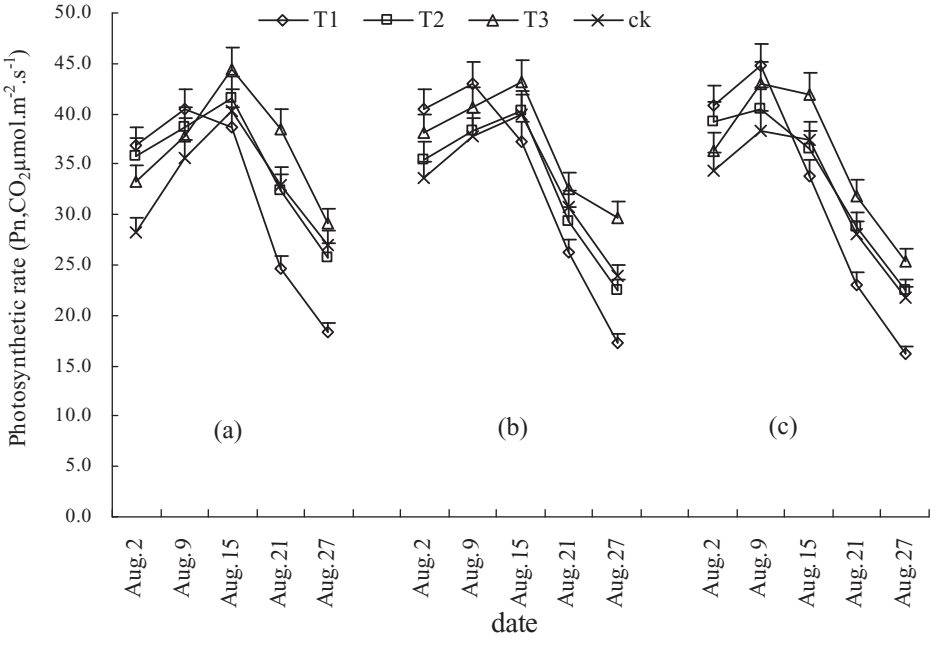

Fig. 1. The effect of source-reducing on photosynthetic rate of pumpkin leaves in different developmental stages. (a) Leaves in front of fruit. (b) Leaves on fruit. (c) Leaves behind fruit.