Light competition in Chinese cabbage/maize strip intercropping systems

Til Feike, Sebastian Munz, Simone Graeff-Hönninger, Qing Chen, Judit Pfenning, Gudrun Zühlke, Wilhelm Claupein

Institut für Pflanzenbau und Grünlandlehre
Universität Hohenheim
Fruwirthstr.23
70599 Stuttgart
tilfeike@uni-hohenheim.de
graeff@uni-hohenheim.de

Abstract: Due to drastic socio-economic changes traditional intercropping systems in China are endangered. New high yielding intercropping systems that can easily be mechanized have to be developed. By using environmental resources more efficiently intercropping often produces higher yields compared to monocropping. Solar radiation as the strongest growth factor plays a key role when designing new intercropping systems. A Chinese cabbage – maize strip intercropping experiment was run at Hohenheim University's research station "Ihinger Hof" in 2009. Photosynthetically active radiation (PAR) was measured regularly in the strips in different distances to the neighboring maize plants. However continuous and simultaneous measurements and thus the direct quantification of differences in daily available PAR were not possible. By adjusting polynomials to the measured timelines and defining sunrise and sunset as the interval borders the integrals of each polynomial could be calculated. Daily PAR was significantly reduced in the first three rows of Chinese cabbage grown next to maize; with the lowest values of 70% and 56% in row one west and east respectively. Reduced PAR led to significant yield decreases in these Chinese cabbage rows. To optimize the spacing in a maize/Chinese cabbage intercropping system PAR availability and tolerance of shading of the subordinate crop will be decisive.

1 Introduction

Adjusting crop production systems to changing environments is a key issue of present agronomic research. Intercropping, the simultaneous cultivation of two or more crops in the same field is a traditional production system in the North China Plain. To maintain this sustainable production system the rapidly increasing use of agricultural machinery has to be recognized. The conversion of the traditional row intercropping systems, which demand an enormous input of manual labor, into strip intercropping systems, which can easily be mechanized, is an appropriate approach to match future conditions.

By a more efficient use of the environmental resources water (WO03), nutrients (Li01) and solar radiation (Ts01; KC93) intercropping often overyields its monocropping equivalents. When developing adjusted strip intercropping systems it is of great importance to ensure an efficient resource use. To optimize the use of photosynthetically active radiation (PAR) the width of the strips of each component crop will be decisive. Therefore availability of PAR at various locations in the strip intercropping system has to be determined to realize an optimal design of such systems.

For determination of PAR the use of handheld devices, which allow flexible measurements of PAR at different heights and locations of a plant canopy is common. However, simultaneous and continuous measurements and thus the comparison of total daily available PAR at different locations in the field are difficult. This paper presents an approach to overcome this problem and enable the extrapolation of a few data points to a daily bases.

2 Materials and Methods

2.1 Field experiment

To test the effects of availability of photosynthetically active radiation on crop growth and yield a strip intercropping experiment was conducted at Hohenheim University's research station Ihinger Hof in 2009. To ensure strong effects on the availability of PAR one dominant and one subordinate component crop were desired. The combination of maize (Zea maize L.) cv. Companireo, an erectophile monocotyledon with Chinese cabbage (*Brassica campestris* L. ssp. *pekinensis*) cv. Kasumi, a planophile dicotyledon additionally met the desire of examining an intercropping system that is of practical importance in China. Alternating strips of maize (12 m) and Chinese cabbage (10 m) were planted in a sequence with four replications. Row orientation was north-south.

PAR was measured using a linear PAR ceptometer (Model AccuPar LP-80, Decagon Devices, Pullman, WA, USA). The measurements were conducted above canopy at various locations in the Chinese cabbage strips, namely row 1,2,3,5, and 7, east and west of each maize strip respectively. The measurements in the present paper were conducted in irregular intervals between sunrise and sunset on 5th of August 2009. Average maize height and LAI were 175 cm and 3.2 respectively.

2.2 Analysis

To estimate the total daily available PAR from the punctual measurements and determine significant differences between the different rows in the Chinese cabbage strips, polynomials of degree four were fit to the measured data points. By defining sunrise and sunset as the interval borders the integrals of each polynomial could be calculated as follows:

$$\int_{sunrise}^{sunset} f(x)\,dx = F(sunset) - F(sunrise) \qquad [1]$$

For determining significant differences between rows in daily available PAR and yield of Chinese cabbage the GLM procedure of SAS vs. 9.1 was employed.

3 Results and discussion

A chronological sequence of measured PAR in different rows of the Chinese cabbage strips is presented in Fig. 1. In the western part of the strips radiation in the first row declined before noon, due to the incipient shading by the neighbouring maize. In contrast the eastern part of the strips suffered from shading in the morning hours and received full radiation in the afternoon.

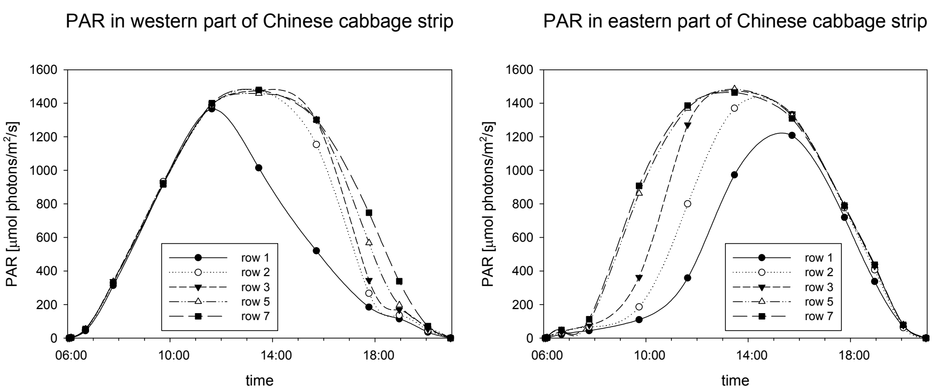

Figure 1: Sequence of intercepted PAR in row 1,2,3,5, and 7 of Chinese cabbage strips

By fitting a polynomial to each data line and comparing the area below the curves by calculating the integral, differences in total daily intercepted PAR were quantified. Coefficients of determination for the polynomials fit to the timelines of each replication varied from R^2=0.831 to R^2=0.998. No significant differences in incoming PAR occurred in the centres of the strips, from row five west to five east (Fig. 2). Strong differences however emerged from row one to three, close to the maize, with differences being more significant in the eastern part. Intercepted PAR was reduced to about 70 % and 56 % in row one west and east respectively.

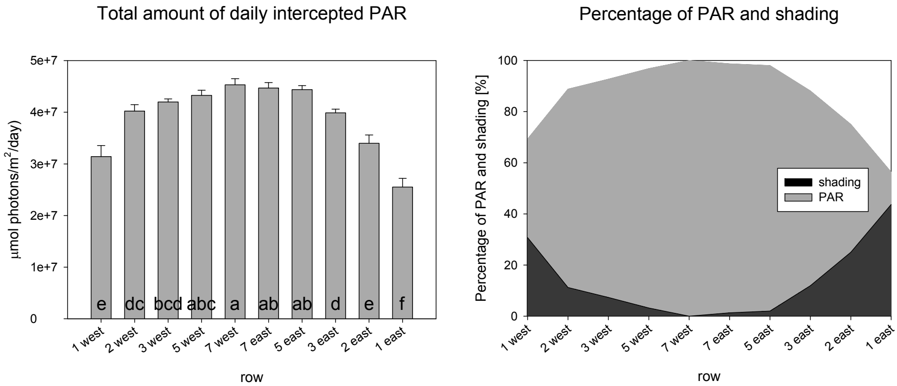

Figure 2: Total amount of daily intercepted PAR (left) and percentage of PAR and shading depending on distance to maize (right) (significance at $\alpha = 0.05$)

The percentage of shading by maize to the neighbouring Chinese cabbage was rapidly declining towards the centre of the strip. Only the yield in both rows one was significantly lower. Rows three and four tolerated significantly lower daily available PAR without significant yield losses.

4 Conclusion

Fitting polynomials to measured PAR timelines and calculating their integrals allowed the quantification of intercepted PAR on a daily scale. For designing an optimized strip intercropping system the knowledge on incoming radiation and shading by the dominant crop are essential to manage the tolerable degree of competition. In a next step the changes of available PAR in Chinese cabbage will be fed to the DSSAT sub-model WEATHERMAN to check simulated plant response to the data obtained in the field experiments. For use in the field it will be essential to adjust the width of strips, as well as row spacing to the solar conditions of the location and shade tolerance of the subordinate crop.

References

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