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Researches on Photosynthetic Efficiency of cassava-peanut Intercropping Impacted by Total Solar Eclipse

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Abstract

On July 22nd, 2009, the total solar eclipse spectacle occurred in Yangtze River in central China. By setting cassava-and-peanut intercropping, we used LI-6400 to study the diurnal variation of photosynthetic efficiency impacted by total solar eclipse. The results showed that: (1) Diurnal variation of atmospheric temperature (Ta), photosynthetic active radiation (PAR) and field CO_2 concentration (Ca) reduced sharply, while atmospheric relative humidity (RH) went up. (2) The intercropping showed a higher resistibility than monoculture did. Besides, cassava and peanut showed a different resistibility, which also verified the theory of intermediate disturbance hypothesis. (3) When the total solar eclipse was over, the net photosynthetic efficiency (Pn) of both cassava and peanut demonstrated a similar declining trend, and the resilience of monoculture was stronger than that of intercropping. Furthermore, in monoculture, the resilience of cassava was stronger than that of peanut.

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Keywords: Total solar eclipse; Monoculture; Intercropping; Resistibility; Resilience

1. Introduction

The earliest recorded eclipse of the sun is the one which happened more than four thousand years ago, an account of which is given in the ancient Chinese classic Shu Ching. A total eclipse of the sun is the most awesome sight in the heavens [1-2]. When the moon takes a bite-size chunk of the sun, it's a partial solar eclipse. When the moon, the earth and the sun become a straight line and the moon completely

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covers over the sun's disk, it's a total solar eclipse. Under clear sky conditions, a number of phenomena can be observed, such as the changing color of the sky and the solar corona [3-4].

The total solar eclipse spectacle swept across the central belt in China on July 22nd, 2009. Even if located on the fringe of the eclipse zone, Yingtan, Jiangxi Province, due to great weather, is a suitable place for the measurement of photosynthetic efficiency.

According to relevant researches, solar eclipse could lead to a complex chemistry-and-dynamic change in the ionized layer. The eclipse is analogous to fast sunrise and sunset. During that short period, big changes have taken place in the ionized layer, such as illumination and ionizing radiation intensity. At first, electron generation rate decreases rapidly, then, mounts gradually after maximum eclipse, and returns to normal when the maximum eclipse is over. Besides, there are remarkable dynamic atmospheric effects. The incoming solar radiation, net radiation and air temperature are significantly affected [5].

2. Experimental details

The experiment plot locates in red soil test base, Jiangxi Province, 28°2′～28°30′ of north latitude, 116°20′～116°51′ of east longitude, belongs to the monsoon climate of subtropical zone. The annual average temperature is 17.7℃ . It has a frost-free period of 270 days. The rainfall averages 1710.4mm a year, concentrated mostly between March and June. It has serious soil erosion in rainy season. Drought arises between July and September, frequently in late summer and autumn.

Table 1 Different Treatment of Peanut and Cassava

Type	Treatments
Monoculture (peanut)	31 rows, 59 holes each row
Monoculture (cassava)	12 rows, 10 plants each row
Intercropping (Ⅰ)	Cassava 4 rows, peanut 27 rows (9 rows between 2 rows of cassava)
Intercropping (Ⅱ)	Cassava 7 rows, peanut 24 rows (4 rows between 2 rows of cassava)
Intercropping (Ⅲ)	Cassava 8 rows (2 rows in 1 group), peanut 23 rows (8 rows on either side, 7 rows in the middle)

This research chose cassava HN-205 and peanut GH-3. Cassava HN-205, the main cultivar, belonging to bitter-type cassava, aka little-leaves cassava, conic, fertilizer-loving, could be harvested 8 months after plantation. Peanut GH-3, proved by Jiangxi Academy of Agricultural Science, is suitable for the application and dissemination of dry land and paddy rice-upland crop rotation cultivation in Jiangxi Province. In this research, randomized block design with five treatments and three replications was applied. There were 15 testing areas in all, and each was 96 square meters (12 meters ×8 meters). The specific treatments are shown in Table 1. On July 22nd, 2009 and the following day, 3 peanuts and 3 cassava of the same size and growth were randomly chosen, and we used LI-6400 to determine the diurnal variation of photosynthesis from top to No. 7 or 9 leave (for cassava, middle lobed of palm leaves) on every 2 hours from 6 a.m. to 6 p.m. The photosynthetic indicators of mensuration include: net photosynthetic rate (Pn, $\mu molCO_2 \cdot m^{-2} \cdot s^{-1}$), transpiration rate (Tr, $mmolH_2O \cdot m^{-2} \cdot s^{-1}$), atmospheric temperature (Ta, ℃), field CO_2 concentration (Ca, μmol·mol-1), photosynthetic active radiation (PAR, $\mu mol \cdot m^{-2} \cdot s^{-1}$), relative humidity (RH, %), etc. Experimental data were analyzed by software Excel and SAS.

3. Results and discussion

3.1 Environmental factors concerning growth influenced by total solar eclipse

On the basis of data collection on July 22nd, 2009 and the following day, the environmental factor data integration and processing is shown Fig.1.

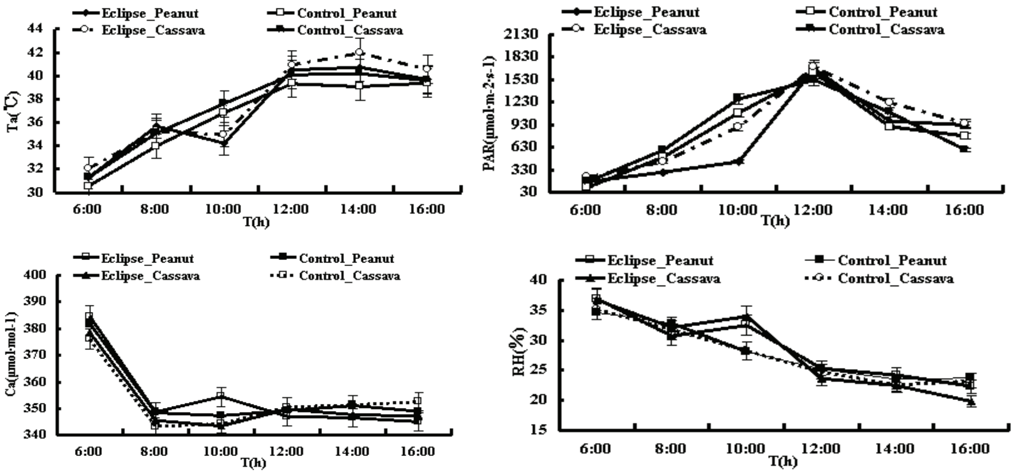


Fig.1 Diurnal Variation of Ta/PAR/CA/RH Impacted by the Total Solar Eclipse

As can be seen from the line graph, Ta decreased obviously from 37℃ to 34℃ at about ten o'clock in the morning. The variation tendency of PAR was consistent with that of Ta, presenting a single peak curve. PAR decreased from eight o'clock to ten o'clock before the flex point occurred. Then, PAR increased gradually. As shown in Fig.1, PAR of cassava decreased from 1273.61 $\mu mol\cdot m^{-2}\cdot s^{-1}$ to 900.67 $\mu mol\cdot m^{-2}\cdot s^{-1}$, and drop extent was 372.94 $\mu mol\cdot m^{-2}\cdot s^{-1}$. Meanwhile, PAR of peanut decreased from 1087.83 $\mu mol\cdot m^{-2}\cdot s^{-1}$ to 437.85 $\mu mol\cdot m^{-2}\cdot s^{-1}$, and drop extent was 649.98 $\mu mol\cdot m^{-2}\cdot s^{-1}$, twice as much as that of cassava. This showed that total solar eclipse had greater influence on PAR of peanut. RAR returned to normal after 12 noon. The changing tendency of Ca and RH was generally contrary to that of Ta and PAR, presenting a U-shaped curve. When the total solar eclipse disappeared, Ca of peanut decreased from 354.46 $\mu mol\cdot mol^{-1}$ to 347.49 $\mu mol\cdot mol^{-1}$, and at the same time, Ca of cassava decreased from 344.37 $\mu mol\cdot mol^{-1}$ to 343.50 $\mu mol\cdot mol^{-1}$. Besides, RH of peanut and cassava rose up to 32.47% and 33.95% respectively, then, decreased sharply to minimum at 4 p.m.

3.2 Net photosynthetic rate (Pn) of different treatments influenced by total solar eclipse

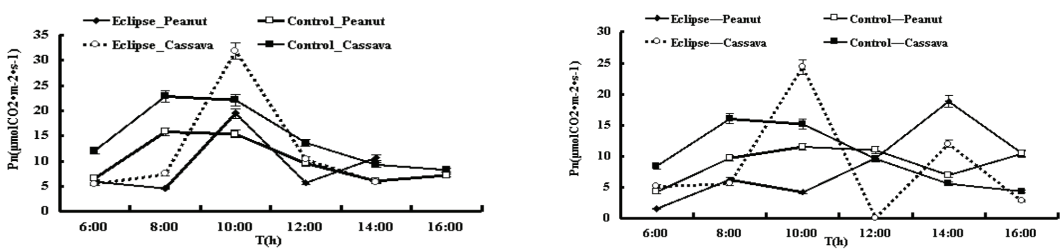
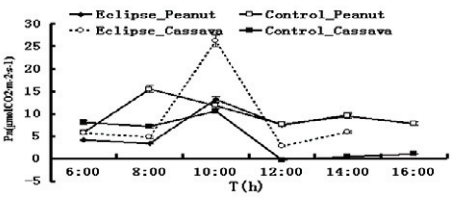


Fig.2 Diurnal Variation of Pn in Monoculture Impacted by Total Solar Eclipse

Fig.3 Diurnal Variation of Pn in Intercropping (Ⅰ) Impacted by Total Solar Eclipse

In monoculture (Fig.2), according to the change of slope from 6:00 to 8:00, the slope of Pn gradually declined from the early stages of total solar eclipse. For peanut, slope of Pn dropped from 4.62 to -0.66, a drop of 5.27. For cassava, slope of Pn dropped from 5.38 to 0.99, a decline of 4.39. At 10:00, Pn of peanut and cassava bounced back. Pn of peanut ascended from 15.36 $\mu molCO_2 \cdot m^{-2} \cdot s^{-1}$ (mean) to 19.47 $\mu molCO_2 \cdot m^{-2} \cdot s^{-1}$, gaining a 26.76% increase. Meanwhile, Pn of cassava increased from 22.11 $\mu molCO_2 \cdot m^{-2} \cdot s^{-1}$ to 31.88 $\mu molCO_2 \cdot m^{-2} \cdot s^{-1}$, gaining a 44.19% increase. In other words, resilience of cassava was stronger when the total solar eclipse was over.

In intercropping (Fig.3), when total solar eclipse came, Pn of both cassava and peanut decreased. As for peanut, slope of Pn dropped from 2.72 to 2.34 (a decrease of 0.38). For cassava, slope of Pn dropped from 3.79 to 0.21 (a decline of 3.58). At 10:00, Pn of cassava rose from 15.18 $\mu molCO_2 \cdot m^{-2} \cdot s^{-1}$ to 24.35 $\mu molCO_2 \cdot m^{-2} \cdot s^{-1}$ (a growth of 60.41%). Meanwhile, Pn of peanut went down from 11.53 $\mu molCO_2 \cdot m^{-2} \cdot s^{-1}$ to 4.21 $\mu molCO_2 \cdot m^{-2} \cdot s^{-1}$ (a drop of 63.49%). After 12 noon, Pn of both peanut and cassava were greatly improved. This demonstrated that the resilience of cassava was stronger than that of peanut, and photosynthetic compensation of peanut lagged behind (after 12 noon).



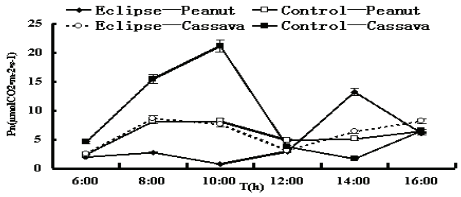


Fig.4 Diurnal Variation of Pn in Intercropping (Ⅱ) Impacted by Total Solar Eclipse

Fig.5 Diurnal Variation of Pn in Intercropping (Ⅲ) Impacted by Total Solar Eclipse

In intercropping (Ⅱ), as shown in Fig.4, impacted by the total solar eclipse, Pn of peanut and cassava dropped, but diurnal changes of Pn of cassava was not obvious and slope of Pn had a drop of 0.02. But Pn of cassava decreased remarkably, from 4.83 to -0.38, a decline of 5.21. At 10:00, Pn of cassava and peanut were compensated. Pn of cassava rose from 10.59 $\mu molCO_2 \cdot m^{-2} \cdot s^{-1}$ to 26.22 $\mu molCO_2 \cdot m^{-2} \cdot s^{-1}$ (a growth of 147.59%), Pn of peanut increased from 11.80 $\mu molCO_2 \cdot m^{-2} \cdot s^{-1}$ to 13.23 $\mu molCO_2 \cdot m^{-2} \cdot s^{-1}$ (a growth of 12.12%).

In intercropping (Ⅲ), as shown in Fig.5, judging by the change of slope from 6:00 to 8:00, the slope of Pn declined from the beginning of total solar eclipse. As for peanut, slope of Pn dropped from 2.86 to 0.40 (a decrease of 2.46). For cassava, slope of Pn dropped from 5.48 to 3.05 (a decline of 2.43). At 10:00, although it could reach to 21.14 $\mu molCO_2 \cdot m^{-2} \cdot s^{-1}$ in normal illumination, Pn of cassava was 7.6 $\mu molCO_2 \cdot m^{-2} \cdot s^{-1}$ (a drop about 64.05%). Meanwhile, Pn of peanut decreased from 8.11 $\mu molCO_2 \cdot m^{-2} \cdot s^{-1}$ (in normal illumination) to 0.73 $\mu molCO_2 \cdot m^{-2} \cdot s^{-1}$, falling by 91%. This showed that restorability of cassava was stronger. After 12 noon, resilience of both peanut and cassava were greatly improved, and resilience of peanut was stronger.

In short, the resistibility of both peanut and cassava under different treatments presented an inconsistent trend. For peanut, the sequence was: intercropping (Ⅰ) (slope of Pn dropped by 0.38) > intercropping (Ⅲ) (slope of Pn dropped by 2.46) > intercropping (Ⅱ) (slope of Pn dropped by 5.21) >monoculture (slope of Pn dropped by 5.27). And for cassava, the sequence was: intercropping (Ⅱ) (slope of Pn declined by 0.02) > intercropping (Ⅲ) (slope of Pn declined by 2.43) > intercropping (Ⅰ) (slope of Pn declined by 3.58) >monoculture (slope of Pn declined by 4.39). Thus, we came to the conclusion that resistibility of intercropping to the influence of total solar eclipse was far more stronger than that of peanut.Besides, the sequence of Pn resilience of cassava was: monoculture

(31.88μmolCO_2·m^{-2}·s^{-1}, shrank 64.05%) > intercropping (Ⅱ) (26.22 μmolCO_2·m^{-2}·s^{-1}, growth of 147.59%) > intercropping (Ⅰ) (24.35 μmolCO_2·m^{-2}·s^{-1}, growth of 60.41%). The sequence of Pn resilience of cassava was the same as that of cassava: monoculture (19.47μmolCO_2·m^{-2}·s^{-1}, growth of 26.76%) > intercropping (Ⅱ) (13.23 μmolCO_2·m^{-2}·s^{-1}, growth of 12.12%) > intercropping (Ⅰ) (4.21 μmolCO_2·m^{-2}·s^{-1}, shrank 63.49%) > intercropping (Ⅲ) (0.73 μmolCO_2·m^{-2}·s^{-1}, shrank 91%). Therefore, we came to the conclusion that resilience of monoculture is stronger than that of intercropping and resilience of peanut is weaker than that of cassava. Besides, resilience of peanut advanced greatly after 12:00, and at this time, Pn of peanut was higher than that of cassava. In short, this phenomenon had something to do with plant compensation mechanism and adaptability to the environment.

3.3 Multiple analysis of variance (ANOVA) with multiple-comparison tests on Pn

As above, the diurnal variation of Pn was restricted by two factors: T_1 (different treatments) and T_2 (different time). From the statistics given in the table (Table 2), it could be seen that Pn of peanut, T_1 and T_2 presented remarkable differences ($p<0.01$) under normal weather. Furthermore, from the analysis of interactive influence (T_1*T_2), the difference ($p>0.05$) was not significant. That is to say, T_1 and T_2 had an effect on Pn of peanut independently. However, Pn of peanut made insignificant differences, implying a great impact by the total solar eclipse.

Pn of cassava showed some differences ($p<0.05$), but the differences were caused not by T_1 ($p>0.05$), but by T_2 ($p<0.01$). During total solar eclipse, Pn of cassava showed notable differences ($p<0.01$). This indicated that Pn of cassava was influenced by total solar eclipse and possessed higher stability.

Table 2 ANOVA with Multiple Tests on Pn of Both Peanut and Cassava

Type	Analysis of Variance		Type Ⅰ/Ⅲ Tests		
	F Stat	Pr>F	Factor	F Stat	Pr>F
Pn of peanut (normal weather)	10.47	0.0005	T_1	13.52	0.0025
			T_2	9.70	0.0006
Pn of peanut (total solar eclipse)	2.84	0.0566	T_1	-----	-----
			T_2	-----	-----
Pn of cassava (normal weather)	4.53	0.0115	T_1	2.08	0.1714
			T_2	5.14	0.0092
Pn of cassava (total solar eclipse)			T_1	3.91	0.0679
			T_2	9.80	0.0005

4. Conclusion

4.1 Diurnal variations of environmental factors concerning growth influenced by total solar eclipse

From the analysis of diurnal variation, Ta, PAR and Ca decreased while RH increased. Ta was undoubtedly dropping when the eclipse came, which had been confirmed by many scholars [6]. Ta began to fall when the sun was covered by half, and Ta reached its lowest point about half an hour later. PAR dropped sharply at 10:00, which was similar with Ta. The decline rate of peanut was higher than that of cassava. At 12:00, PAR of both peanut and cassava returned to normal, and showed a sign of downtrend (higher than normal condition) after midday. The change trends of Ca and RH was inversely related to that of PAR and Ta, presenting a U-shaped curve. Ca of both peanut and cassava decreased, and the drop of peanut was slightly faster than that of cassava. Besides, RH of both peanut and cassava rose up. RH of peanut went up to 32.47% when RH of cassava rose up to 33.95%. But, following the end of total solar eclipse, RH declined rapidly, and sank to its lowest level (lower than the normal condition) at 16:00.

4.2 Resistibility and resilience of crops during total solar eclipse

Pn of peanut and cassava had varying degrees of decline when total solar eclipse came, and different treatments had different degrees. Pn of cassava in intercropping (Ⅱ) and Pn of peanut in intercropping (Ⅰ) were influenced little by total solar eclipse. In intercropping (Ⅲ) and monoculture, Pn of both peanut and cassava decreased, but Pn in monoculture dropped significantly. All in all, in respect of resistibility to total solar eclipse, compared with monoculture, intercropping gained an edge.Intermediate disturbance hypothesis, proved by experts and scholars, is universally accepted. And the further analysis could discover that, as for the resistibility of peanut, the sequence was: intercropping (Ⅰ) > intercropping (Ⅲ) > intercropping (Ⅱ) >monoculture. And for cassava, the sequence was: intercropping (Ⅱ) > intercropping (Ⅲ) > intercropping (Ⅰ) >monoculture. To some extent, these proved the intermediate disturbance hypothesis, namely, intermediate monoculture could improve the adaptability of crops to environment. And in this experiment, the adaptability could be identified as the resistibility to the total solar eclipse.Stability of ecosystem relys not only on the resistibility to environmental events, but also on the resilience. Resilience derives from Latin resilio, from 1970s, put forward as the system recovery while experiencing compression and the ability to return to the initial state. Holling [7] applied the resilience concept to ecosystem for the first time, defined as “a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables.”At the end of total solar eclipse (about 10:00), Pn resilience of both peanut and cassava of different treatments showed the same decreasing trend (monoculture > intercropping (Ⅱ) > intercropping (Ⅰ) > intercropping (Ⅲ)). Thus, intercropping didn’t present its unique advantages while monoculture showed advantages. In the process of hundreds of thousands of years of evolution and abnormal natural disasters with heavy consequences, crop, in its original state, usually exists in the form of monoculture while intercropping is associated with the evolution of modern society. Therefore, crops in monoculture have the strong resilience to form the defense mechanism in evolutionary process. Moreover, in monoculture, instant resilience of cassava was stronger than that of peanut, which had been proved by above (ANOVA with Multiple Tests on Pn). After 12:00, resilience of peanut rose up quickly, which might have something to do with compensation mechanism and adaptability to environment. Admittedly, what we have observed in this study is far from complete and it requires further research.

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