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Influence of shade regimes on photosynthetic rate and stomatal characters of ginger (*Zingiber officinale* R.)

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Abstract

The study conducted on the influence of shade regimes on photosynthetic rate and stomatal characters of ginger (*Zingiber officinale* R.) indicated that the highest photosynthetic rate was in plants grown under open condition followed by plants grown at 20 and 40 per cent shade levels. Regression coefficient analysis demonstrated that photosynthetic rate, stomatal conductance, transpiration rate, stomatal index and stomatal frequency significantly reduced linearly with increasing level of shade, whereas stomatal resistance increased linearly with increasing level of shade. The enhanced rhizome yield under low levels of shade (20 and 40 per cent) compared to open condition (where photosynthetic rate was maximum) may be mainly due to the higher leaf area resulted in the plants grown under 20 and 40 per cent shade levels.

Key words: ginger, photosynthetic rate, shade, *Zingiber officinale*.

Introduction

Though ginger is cultivated as a monocrop, intercropping is also adapted for utilizing shaded situations. The information from India and abroad that ginger is a shade tolerant / loving crop (Aclan & Quisumbing 1976; Ravisankar & Muthuswamy 1987; KAU 1992) suggests further studies with regard to the rate of photosynthesis under different shade levels and consequent translocation of photosynthates to the underground rhizome which is the economically important part. The investigation was undertaken to study the influence of shade regimes on photosynthetic rate and stomatal characters of ginger.

Materials and methods

Pot culture studies were conducted during 1996-97 and 1997-98 to assess the influence of shade levels on photosynthetic rate and stomatal behaviour, at Coconut Research Station, Balaramapuram, Thiruvananthapuram, Kerala, India. The climate of the experimental site was humid tropical. Rhizomes of ginger cultivar Rio-de-Janeiro were planted in mud pots (size 30 cm x 35 cm) filled with potting mixture. The treatments included were five levels of shade (0, 20, 40, 60 and 80 per cent). The experiment was laid out in completely randomized design with four replications. The required shade levels were provided by *pandal* with high density polyethylene threads. The mean photo-

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synthetically active radiation (PAR) under 0, 20, 40, 60 and 80 per cent shade levels were 1461, 1120, 825, 550 and 260 mmol $m^{-2} s^{-1}$. The portable photosynthesis system (LCA – 4) was used for measuring photosynthetic rate and related parameters at 180 days after planting. The data were analysed by linear regression analysis and analysis of variance technique (Gomez & Gomez 1984; Snedecor & Cochran 1967).

Results and discussion

The ANOVA shows that there was a significant influence of shade on various parameters. However, when the linear contrast was tested (Gomez & Gomez 1984), it was also noticed that there was significant linear trend in respect of these parameters with progressive levels of shade. The regression coefficient demonstrated that all the characters, except stomatal resistance have been significantly reduced with increasing level of shade (Table 1).

The observed values of photosynthetic rate and related parameters of ginger at different shade levels are given in Table 2. The estimated values in respect of each shade level using the fitted regression model are also given (values in parentheses).

As the shade increased there was a proportionate decrease in photosynthetic rate and stomatal conductance. Stomatal characters such as size and frequency have direct correlation with stomatal conductance. From the study it is evident that the stomatal index and stomatal frequency were maximum at 0 followed by 20 and 40 per cent shade levels. As the shade increased there was a proportionate decrease in stomatal index and sotmatal frequency. This may be the reason for higher stomatal conductance under open condition and low shade levels. Transpiration rate was maximum when plants were grown in open condition. High light intensity increased the stomatal frequency and perhaps this might have influenced the transpiration rate. Leaf resistance to transpiration can widely vary as environmental factors influence stomatal apertures. High rate of transpiration observed in open and lower levels of shade may be due to high stomatal index and stomatal frequency.

Ginger plants grown under 20 and 40 per cent shade levels produced significantly higher leaf area (Table 3) compared to the plants grown under open condition. This indicated that 20 and 40 per cent shade levels were favourable for enhanced leaf area in ginger.

Data on pooled analysis revealed that dry ginger yield was maximum when the plants were grown under 20 per cent shade level followed by 40 per cent shade level (Table 3). The enhanced rhizome yield under low levels of shade (20 and 40 per cent) compared to open (where photosynthetic rate was maximum) may

Table 1. Linear regression coefficients in respect of photosynthetic rate and related characters of ginger under different shade levels at 180 days after planting

Parameter	a		b		R^2		t_{18} of b	
	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98
Photosynthetic rate (μ mol $m^{-2}s^{-1}$)	5.7450	6.3360	-0.0750	-0.0604	0.72	0.83	6.746	9.296
Stomatal conductance (μ mol $m^{-2}s^{-1}$)	0.0345	0.0660	-0.0004	-0.0005	0.81	0.71	8.722	6.685
Stomatal resistance (μ mol $m^{-2}s^{-1}$)	20.6347	13.1201	1.3963	0.3300	0.62	0.74	5.446	7.080
Transpiration rate (mol $m^{-2}s^{-1}$)	1.1685	1.6630	-0.0124	-0.0146	0.70	0.75	6.439	7.278
Stomatal index	11.2050	11.7450	-0.0612	-0.0716	0.76	0.82	7.476	9.068
Stomatal frequency	3.6000	3.9000	-0.0188	-0.0225	0.66	0.68	5.883	6.114

Table 2. Photosynthetic rate and related parameters of ginger under different shade levels at 180 days after planting

Parameter	Shade level (S)									
	S_0 (0 %)		S_1 (20 %)		S_2 (40 %)		S_3 (60 %)		S_4 (80 %)	
	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98	1996-97	1997-98
Photosynthetic rate	7.54	6.32	2.51	5.61	1.80	3.36	1.16	2.45	0.72	1.86
(μ mol $m^{-2}s^{-1}$)	(5.74)	(6.34)	(4.24)	(5.13)	(2.75)	(3.92)	(1.25)	(2.71)	(-0.25)	(1.50)
Stomatal conductance	0.04	0.07	0.02	0.05	0.02	0.04	0.01	0.04	0.01	0.03
(μ mol $m^{-2}s^{-1}$)	(0.03)	(0.07)	(0.03)	(0.06)	(0.02)	(0.05)	(0.01)	(0.04)	(0.01)	(0.03)
Stomatal resistance	24.12	14.13	57.46	21.35	71.10	25.46	74.57	25.72	155.19	44.94
(μ mol $m^{-2}s^{-1}$)	(20.63)	(13.12)	(48.56)	(19.72)	(76.48)	(26.32)	(104.41)	(32.92)	132.34)	(39.52)
Transpiration rate	1.43	1.73	0.61	1.29	0.59	1.10	0.50	0.76	0.25	0.53
(mol $m^{-2}s^{-1}$)	(1.17)	(1.66)	(0.92)	(1.37)	(0.67)	(1.08)	(0.43)	(0.79)	(0.18)	(0.49)
Stomatal index	10.45	10.83	10.55	11.45	9.45	9.20	7.46	7.08	5.88	5.85
	(11.21)	(11.75)	(9.98)	(10.31)	(8.76)	(8.88)	(7.53)	(7.45)	(6.31)	(6.02)
Stomatal frequency	3.50	3.75	3.25	3.50	3.00	3.25	2.50	2.50	2.00	2.00
	(3.60)	(3.90)	(3.23)	(3.45)	(2.85)	(3.00)	(2.48)	(2.55)	(2.10)	(2.10)

Values within parentheses are the estimated values of the parameters on shade using the regression model.

be mainly due to the enhanced leaf area.

It can be concluded from the study that significant increase in rhizome yield was obtained when ginger was grown under 20 per cent shade level. In open condition, lower stomatal resistance and higher stomatal frequency with higher rate of transpiration might have resulted in internal deficiencies of water, which may cause the scorching and wilting of the leaf. But under low shade levels, the production and retention of leaves were higher. Under shaded condition, reduced radiation may prevent scorching or wilting of leaves caused by marked increase in temperature within the leaf tissue from direct sun light (Aasha 1986) and thereby increase the leaf life resulting in maximum retention of leaves. When photosynthetic surface is increased on per plant basis the total quantity of photosynthates will also be higher. Though, the photosynthetic rate was less, the yield was high at 20 per cent shade level. The photosynthetic rate of plants grown under open condition was maximum, but this did not reflect in rhizome production, but the rhizome production was lower compared to the plants grown under 20 per cent shade level. The probable reasons for low yield under open condition may be due to lower leaf area, more photooxidation and inefficient translocation of photosynthates (Sreekala 1999).

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Table 3. Effect of shade levels on leaf area and dry rhizome yield of ginger

Shade level	Leaf area (cm^2)			Dry rhizome yield (g $plant^{-1}$)		
	1996-97	1997-98	Pooled mean	1996-97	1997-98	Pooled mean
S_0 (0 %)	4170.16 ^{b}	4873.19 ^{ab}	4521.67 ^{b}	26.54 ^{c}	32.90 ^{b}	29.72 ^{c}
S_1 (20 %)	6967.03 ^{a}	6018.09 ^{a}	6492.56 ^{a}	50.47 ^{a}	48.17 ^{a}	49.32 ^{a}
S_2 (40 %)	6608.75 ^{a}	6376.59 ^{a}	6492.67 ^{a}	40.82 ^{b}	42.99 ^{a}	41.90 ^{b}
S_3 (60 %)	3611.13 ^{b}	4060.56 ^{bc}	3835.84 ^{bc}	24.52 ^{c}	32.51 ^{b}	28.52 ^{c}
S_4 (80 %)	2509.59 ^{b}	2797.28 ^{c}	2653.44 ^{c}	19.19 ^{c}	20.06 ^{c}	19.62 ^{d}

Values (mean) within a column followed by the same letters are not significantly different at 1 per cent level.

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