The interactive effect of the elevated CO_2 and moisture stress on the photosynthesis in *Brassica* leaves at different canopy positions

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Abstract

Brassica produces important edible oil consumed in South Asian countries including India. Production of *Brassica* crop in India suffered because its growing area is largely rain fed and this crop experiences adverse stress effect at various stages of growth (Uprety and Rabha 1999). The interactive effect of the elevated CO_2 and temperature on *Brassica* species was studied using Free Air CO_2 enrichment (FACE) facility for CO_2 enrichment. The interactive effect of CO_2 and temperature on the plant was studied using leaves at different canopy positions. The contribution of a temperature, light and relative humidity. has been studied with the help of correlation analysis between these environmental factors and rate of photosynthesis in the top, middle and lower leaves of the canopy.

Key words: Ambient CO_2, *Brassica*, Canopy, Carbon dioxide, Elevated CO_2 and Photosynthesis

Introduction

The anthropogenic accumulation and rise of atmospheric CO_2 is an important global issue of present time, which effectively influence the productivity of crop plants. South Asian regions including India which depends upon agriculture particularly on crops for their food security will be most vulnerable to the changed climatic conditions in future. (Long *et al.* 2004). The potential consequence of the rise in atmospheric CO_2 concentration is its effect on the process of photosynthesis, which contributes significantly to the productivity of crop plants. (Uprety *et al.* 1995 and Kimball *et al.* 2002). The increasing CO_2 also causes global warming by absorbing long wave heat radiations. Investigations on global climate changes have been mostly done on plant responses to high CO_2. To understand the responses of the plant system to global climate change, a careful examination of the combine effect of temperature and carbon dioxide on plant was required. The selection of varieties likely to be responsive under the conditions of changed CO_2 concentration and temperature is a major imperative of this study. The response of Brassica crop to the changed CO_2 and temperature conditions was studied in this investigation.

Material and Method

Brassica juncea cv "RH-30" and *Brassica campestris* cv "Pusa gold" were grown in FACE field. Moisture stress treatment was given by withholding irrigation eight days between first flower initiation to 50% flowering to reach the soil moisture 8-10%. Control plants were grown in the field (ambient CO_2 level varying from 371-376 μmol mol $^{-1}$) with 23-25% moisture, 50 meters away from the FACE ring. CO_2 enrichment to 550 μmol mol $^{-1}$ in the FACE ring was done by continuously injecting 100% CO_2 and its concentration was regulated through PID valves controlled by computer system. The wind speed and wind direction signals regulate the computer control in the CO_2 concentration measuring devices. Three replicates of each treatment were taken for every observation. The measurement of photosynthesis, temperature, light intensity and relative humidity at different canopy such as top, middle and lower was recorded using LICOR 6200, IRGA. This paper reports the observations recorded at flowering stage. i.e.60 (DAS) days after sowing. The flowering stage has been selected for taking observations due to its maximum susceptibility to elevated CO_2 and temperature interactions in *Brassica* crop (Uprety and Rabha 1998) plants were grown with 45cm inter row spacing and 20 cm space between the plants. NPK fertilizers were applied at the rate of 30+30:60:40 Kg^{-1} ha. Half of the nitrogen was applied as basal dose and another half at flowering. The relative humidity, light intensity and temperature at the different canopy was measured from 10 cm above the leaf by tele thermometer (Tela temp, Infrared thermometer Model AG 42D).

Results and Discussion

The observations on the interactive effect of elevated CO_2 and moisture stress on leaf photosynthesis at different canopy levels are tabulated and described below. (Table 1)

It was observed that elevated CO_2 significantly increased the rate of photosynthesis in the leaves irrespective of their position, stress treatment and variety the increase was as high as 20%.

Moisture stress brought about significant reduction on the photosynthesis of all the leaves irrespective of their position, variety and CO_2 treatments. The reduction was about 9.6%.

The rate of photosynthesis was 4.5% greater in the variety *Brassica juncea* "RH-30" compared with that of variety *Brassica campestris* "Pusa gold".

The leaf photosynthesis at different canopy levels varied as 18.15 μ mol m^{-2} s^{-1} in top 15.56 at middle and 13.9 in lower leaves of canopy respectively under ambient condition whereas, under elevated CO_2 photosynthesis ranged as 19.26, 16.26 and 15.36 in the top, middle and lower respectively. The CO_2 induced increase was 9.5% in top, 4.3% in middle and 5.86% in lower canopy leaf.

Elevated CO_2 brought about increase in photosynthesis 9.8% in top leaves, 7.3% in middle leaves and 2.4% in lower leaves in *Brassica campestris* cv "Pusa gold" under irrigated whereas, under moisture stress the CO_2 induced increase in this variety was as high as 16% in top and middle leaves and 8% in lower leaves. Similarly in case of variety *Brassica juncea* cv "RH-30", elevated CO_2 significantly increased the rate of photosynthesis It was 14% in top leaves, 8.76% in middle and 12.8% in basal leaves under irrigated condition. The increase under moisture stress condition was 18% in top, 10% in the middle and 19.4% in basal leaves.

Such a study has been explained by Loumala *et al.* (*2006*) in case of Scots pine needles as the processes of acclimation. However, they have not analyzed the climatic parameters at different levels of cohorts of Scot pine. Kimball *et al.* (1995) explained such processes as the impact of the senescence in wheat leaves. However, Morrison and Gifford (1984) related these changes in photosynthesis to the CO_2 induced water status of wheat leaf. In the present study considering all these impact explanations it was demonstrated that top leaf photosynthesis was more responsive to elevated CO_2 under the higher light intensity i.e. More than 1000 μmol mol^{-1} light intensity whereas, the impact on the leaves at middle canopy levels was largely dependent on the light filtered from the top leaf as well as the critical temperature available for the processes of photosynthesis The lower leaf photosynthesis was affected by relative humidity parameter and was significantly lower due to lesser penetration of light from top and middle leaf.

The correlation between the rate of photosynthesis and temperature was maximum in the top leaf ranging the R-value 0.6 to 0.8 in both the cultivars. However, the correlation was lower under stress condition it was also observed that the correlation values were negative in the leaves located in lower canopy levels.

The correlation of photosynthesis with the light intensity was maximum in top leaf and minimum at in lowest canopy level, however, such correlation was not observed under moisture stress condition.

A strong positive correlation (R value ranging between 0.8 to 0.9) between photosynthesis and Relative humidity in top and middle leaf in "RH-30". However, such a relationship was not observed in Pusa gold.

The correlation study demonstrated that the influence of light in determining the response of photosynthesis was significantly greater in top leaf followed by middle leaf whereas, the light effect was negligible in case of lower leaves. However, the correlation appears to be weaker between the light intensity and photosynthesis. The influence of temperature in determining the rate of photosynthesis in top, middle and lower leaves appears to be highly significant contributing relatively more than the light effect. The effect of variable relative humidity on the rate of photosynthesis of leaves at various positions of canopy demonstrated that at less than 50% RH the impact of CO_2 on photosynthesis was negligible whereas, the lower leaves where the RH was more than 50% its impact on the photosynthesis was significant, though the contribution was on the weaker side.

The impact of various factors on the response of elevated CO_2 to the photosynthesis in leaves at different positions of canopy indicated that the temperature changes influences maximum followed by relative humidity and light intensity. Future studies in this area are in progress.

Conclusions

The present study on the contribution of temperature light and relative humidity to the response of brassica leaf photosynthesis demonstrated that the influence of light was greater in top leaves followed by middle leaf and negligible in lower leaf. The influence of temperature appears to be significantly more than light in determining the response at various canopy levels. The relative humidity below 50% showed poor correlation with the response in photosynthesis. This dynamic response of elevated CO_2 was greater in *Brassica juncea* RH-30 compared to *Brassica campestris* Pusa Gold.

Table 1. The response of Brassica leaf photosynthesis(μ mol m^{-2} s^{-1}) to the interaction of elevated CO_2 and moisture stress at different canopy levels

Variety	Treatment	Top canopy leaf	Middle canopy leaf	Lower canopy leaf
V1 *Brassica campestris* Pusa Gold	Ambient CO_2			
	Irrigated	17.96	15.75	14.90
	Moisture stress	16.63	13.91	12.62
V1 *Brassica campestris* Pusa Gold	Elevated CO_2			
	Irrigated	19.96	16.91	15.27
	Moisture stress	19.38	16.17	13.62
V2 *Brassica juncea* *RH-30*	Ambient CO_2			
	Irrigated	20.17	17.10	15.45
	Moisture stress	17.85	15.51	12.65
V2 *Brassica juncea* RH-30	Elevated CO_2			
	Irrigated	22.98	18.61	17.44
	Moisture stress	21.06	17.09	15.11

CD at 5%

Main factors
CO_2 0.452
Moisture stress 0.452
Canopy 0.301
Variety 0.452
Interactions
CO_2 × Moisture stress 0.452
CO_2 × Canopy 0.301
CO_2 × MS x variety NS
CO_2 × variety 0.452
CO_2 × MS × variety NS
CO_2 × canopy × variety 0.452
MS × canopy × variety NS
CO_2 × MS × Canopy × variety 0.301

Table 2. Correlation coefficient study between the photosynthesis and environmental parameters in *Brassica* species

A. Correlation between light intensity and rate of photosynthesis

Variety	Treatment	Top canopy leaf	Middle canopy leaf	Lower canopy leaf
V1	**Ambient**			
Brassica campestris	Irrigated	0.82570	0.97989	0.649957
Pusa Gold	Moisture stress	0.31920	0.27644	0.216088
V1	**Elevated**			
Brassica campestris	Irrigated	0.98598	0.70925	0.569551
Pusa Gold	Moisture stress	0.24799	0.26395	0.251797
V2	**Ambient**			
Brassica juncea	Irrigated	0.94325	0.89448	0.59249
RH-30	Moisture stress	0.40608	0.37411	0.21797
V2	**Elevated**			
Brassica juncea	Irrigated	0.94445	0.98138	0.57266
RH-30	Moisture stress	0.48744	0.86354	0.26457

B. Correlation between the temperature and rate of photosynthesis

Variety	Treatment	Top canopy leaf	Middle canopy leaf	Lower canopy leaf
V1	Ambient			
Brassica campestris	Irrigated	0.82297	0.62170	0.57891
Pusa Gold	Moisture stress	0.79524	0.32747	-0.45392
V1	Elevated			
Brassica campestris	Irrigated	0.91917	0.85454	0.61745
Pusa Gold	Moisture stress	0.79354	0.54470	-0.32033
V2	Ambient			
Brassica juncea	Irrigated	0.68061	0.32515	0.31813
RH-30	Moisture stress	0.32878	0.28795	-0.21049
	Elevated			
V2	Irrigated	0.81711	0.79932	0.54484
Brassica juncea RH-30	Moisture stress	0.73172	0.61840	-0.37960

C. Correlation between relative humidity and rate of photosynthesis

Variety	Treatment	Top canopy leaf	Middle canopy leaf	Lower canopy leaf
V1	Ambient			
Brassica campestris	Irrigated	0.77112	0. 70791	0.93007
Pusa Gold	Moisture stress	0.50409	0.64155	0.88570
V1	Elevated			
Brassica campestris	Irrigated	0.87075	0.71639	0.97241
Pusa Gold	Moisture stress	0.83685	0.64421	0.46353
V2	Ambient			
Brassica juncea	Irrigated	0.86677	0.72752	0.63357
RH-30	Moisture stress	0.74927	0.54635	0.62469
	Elevated			
V2	Irrigated	0.99693	0.89989	0.59303
Brassica juncea RH-30	Moisture stress	0.80911	0.69983	0.56908

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