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Effect of Drought Stress on Photosynthetic Rate of Four Rapeseed (*Brassica napus*) Cultivars

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Abstract: The aim of this research was to investigate SPAD meter readings variations of rapeseed leaves under different treatments. A pot experiment was conducted at a controlled glasshouse in College of Agriculture, Shiraz University, Shiraz, Iran in 2006. Treatments were various rapeseed cultivars (Hayola 401, Hayola 308, Option and RGS) and irrigation regimes (FC (non-stress), 75 FC, 50 FC and 25% FC). The factorial set of treatments was arranged within a randomized complete block design with three replications. The results showed that with increase in drought stress, SPAD meter readings (the relative chlorophyll concentration of leaves) were decreased. Results showed that, drought stress had a significant effect on net photosynthesis (A), stomatal conductance (g_s) intercellular CO_2 concentration (C_i) and leaf area (LA) of rapeseed at both vegetative and flowering stages. In general, Hayola 401, had the highest yield in both control and drought treatments, followed by Hayola 308, whereas RGS had the lowest yield among the cultivars. Hayola 401 and Hayola 308, had the highest g_s in control and the lowest g_s in drought treatments. Cultivars tolerance rankings in this study, was Hayola 401, Hayola 308, Option and RGS. Information obtained in this study may be useful for breeders to introduce suitable drought resistant rapeseed cultivars under arid regions.

Key words: Net photosynthesis, chlorophyll concentration, SPAD meter readings, water regimes, stomatal conductance

INTRODUCTION

Rapeseed, from Brassicaceae, provides a convenient alternative in cereal-based agricultural systems, for its broad leaves and capacity to be a break crop in continuous run of cereals. It is also becoming a popular oilseed crop in Iran, including Fars Province, due to its high oil and protein contents.

Drought is a major abiotic constraint responsible for heavy production losses (Khan *et al*., 2007; Ricciardi *et al*., 1997). This stress is considered as one of the most important limiting factors for rapeseed growth and production. Photosynthetic activity is also hampered under water deficit conditions and one of the earliest plant responses includes stomatal closure, which limits CO_2 diffusion into chloroplast (Muller and Whitsitt, 1996) and reduce photosynthetic activity substantially and eventually causes yield reduction (Wilhite, 1993). Drought stress affects crops growth (Gabriela and Foyer, 2002), photosynthesis (Legg *et al.*, 1997) and leaf senescence. The stress affects almost all plant processes; however, stress response depends on the intensity, rate and duration of exposure to stress and the stage of crop growth (Brar *et al*., 1990). Reduction in photosynthesis in water stressed leaves may be due to stomatal closure (Hsiao, 1973). The chlorophyll meter (or SPAD meter) is a simple portable diagnostic tool that measures the greenness or the relative chlorophyll concentration of leaves (Netto *et al*., 2005). There is no evidence about SPAD meter reading variations induced by drought stress levels in rapeseed cultivars. Moreover, there is no information about the photosynthesis rate and leaf gas exchange characteristics of rapeseed cultivars.

The objectives of this research were to investigate (1) SPAD meter readings variation of rapeseed leaves under drought stress, (2) the net photosynthesis (A), stomatal conductance (g_s), leaf area (LA) and intercellular CO_2 concentration (C_i) of rapeseed cultivars at both vegetative and flowering growth stages.

MATERIALS AND METHODS

Four rapeseed cultivars (Hayola 401, Hayola 308, RGS and Option) were compared under drought stress FC (non-stress), 75, 50 and 25% FC on pot weight basis in a pot experiment at the experimental glasshouse of Department of Crop Production and Plant Breeding, College of Agriculture, Shiraz University, Shiraz, Iran in

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one season of the year 2006. Rapeseed cultivars were grown in pots containing 5 kg soil. Six seeds per pot were sown and thinned into three plants per pot at 3 leaf stage. Plants were irrigated up to FC for three weeks after sowing and then were subjected to four mentioned irrigation regimes. The factorial set of treatments was arranged within a randomized complete block design with three replications. At stem elongation SPAD meter readings were recorded on up per leaves of each plant and the mean reading was noted. Plants were harvested at maturity for yield and yield components. A, g_s and C_i were measured using photosynthesis meter (LCi, UK) at both vegetative and flowering stages. Data were subjected to analysis of variance (ANOVA) and the treatment means were compared (LSD 5%) using SAS Software (2000).

RESULTS

SPAD readings: Across drought stress levels, the differences among cultivars (Hayola 401, Hayola 308, RGS and Option) for SPAD readings were significant ($p \leq 0.01$, Table 1). Option and Hayola 308 had the highest and the lowest SPAD readings, respectively (Table 1). There was a significant drought-cultivar interaction for SPAD meter readings. With increasing drought stress levels SPAD readings were decreased. However, there were no significant differences between control and low drought stress level for the trait. Among the cultivars, option showed the highest and Hayola 308 showed the lowest SPAD meter readings, respectively.

Net photosynthesis (A), stomatal conductance (g_s), leaf area (LA) and intercellular CO_2 concentration (C_i): Drought stress had a significant effect on A, g_s, C_i and LA at both vegetative and flowering stages of rapeseed. Although, at vegetative stage there were no differences between control and 75% FC for A and g_s, C_i and LA, indicating a significant decline even at 75% FC as compared with non-stressed (control) condition. There were significant decrease for A and g_s even in lowest drought stress level at flowering stage (Table 2). Cultivars Hayola 401 and RGS had the highest and the lowest values for both A and g_s, respectively. Hayola 401 showed the highest whereas, RGS showed the lowest value for LA. The highest and the lowest values of C_i were obtained for Hayola 401 and RGS, respectively (Table 2). Interaction between cultivar and drought stress was not significant for A, g_s, LA and C_i values. There was a significant relationship between A and g_s at both vegetative and flowering stages (Fig. 1, 2).

Yield and yield components: Hayola 401 and Hayola 308 had the highest values of yield under both control (non-stressed) and drought stress conditions. RGS produced the lowest yield at both conditions (Table 1). There was a significant correlation between g_s and cultivars yield at vegetative ($r = 0.66$, $p \leq 0.01$) and flowering ($r = 0.89$, $p \leq 0.01$) stages. These results indicated that across drought stress, the cultivars were significantly different ($p \leq 0.01$) in regard to 100 seed weight, number of siliques per plant, number of seeds per

Table 1: SPAD meter readings, yield and yield components of four rapeseed cultivars under drought stress

Treatments	SPAD meter reading	Seed yield (g pot^{-1})	100 seed weight (g)	Silique length (cm)	No. of seeds per silique	No. of siliques per plant
Cultivars						
Hayola 401	48.40b	0.96a	0.323a	3.94a	14.80a	21.83a
Hayola 308	43.45d	0.84b	0.293a	3.95a	13.79b	20.41a
RGS	46.67c	0.40d	0.218b	3.51b	11.08d	18.70b
Option	52.61a	0.51c	0.246b	3.59b	12.54c	15.81b
Water regimes						
Control	54.11a	1.67a	0.314a	4.54a	19.06a	30.25a
75% FC	53.91a	0.68b	0.306a	3.81b	14.29b	18.83b
50% FC	45.47b	0.28c	0.234b	3.41c	11.28c	17.75c
25% FC	37.64c	0.14d	0.225b	3.22c	7.77d	10.33d

Means followed by common letter(s) in each column are not significantly different (LSD test, $p \leq 0.05$)

Table 2: Net photosynthesis (A), stomatal conductance (g_s), intercellular CO_2 concentration (c_i) and leaf area (LA) of four rapeseed cultivars under drought stress at two growth stages

	A (μmol m^{-2} sec^{-1})		g_s (mol m^{-2} sec^{-1})		c_i (mol m^{-2} sec^{-1})		
Treatments	Vegetative	Flowering	Vegetative	Flowering	Vegetative	Flowering	LA (cm^2)
Cultivars							
Hayola 401	19.28a	18.81a	0.61a	0.22a	238.37a	232.56a	398.6a
Hayola 308	18.66ab	15.68b	0.53b	0.18b	233.50 b	223.68b	343.58b
RGS	16.47c	11.13d	0.43c	0.13d	215.45d	200.36d	329.41b
Option	18.08b	12.29c	0.48bc	0.15c	224.29c	208.80c	283.13c
Water regimes							
Control	24.19a	21.55a	0.66a	0.35a	248.50a	237.65a	565.64a
75 % FC	23.65a	17.48b	0.62a	0.18b	233.00b	219.17b	441.65b
50 % FC	14.32b	11.05c	0.47b	0.10c	221.00c	209.96c	217.75c
25 % FC	10.59b	7.81d	0.29c	0.07d	210.25d	198.69d	129.68d

Means followed by common letter(s) in each column are not significantly different (LSD test, $p \leq 0.05$)

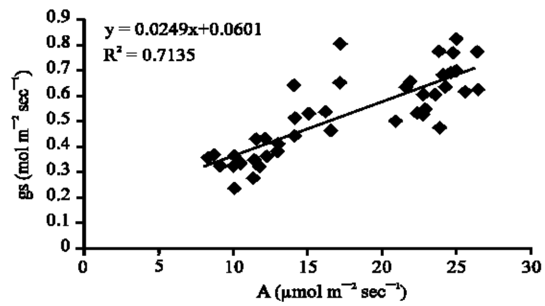

Fig. 1: Relationship between stomatal conductance and photosynthesis rate of four rapeseed cultivars in response to drought stress at vegetative stage

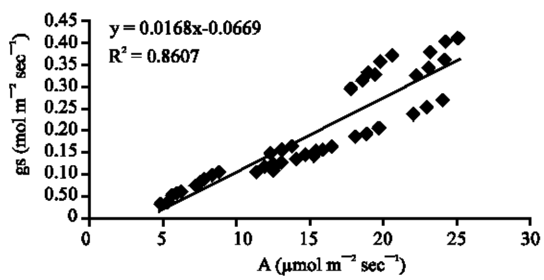

Fig. 2: Relationship between stomatal conductance and photosynthesis rate of four rapeseed cultivars in response to drought stress at flowering stage

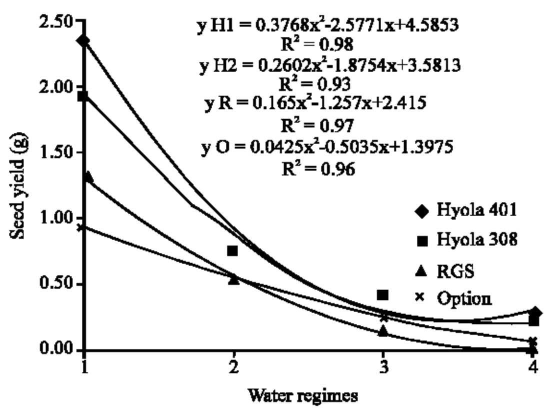

Fig. 3: Rapeseed cultivars yield responses to the various water regimes. Lines represented the fitted quadratic models for each cultivar

silique and silique length (Table 1). Hayola 401 and RGS had the highest and the lowest values for the above mentioned traits, respectively. There was no significant difference between drought treatments; (control and 75% FC and also between 50 and 25% FC) for 100 seed weight. Hayola 401 and Hayola 308 were in the same statistical group for 100 seed weight and silique length. RGS and Option were also in the same statistical group for the two mentioned traits (Table 1). With increasing drought stress in all cultivars, rapeseed yield decreased. Models were fitted to rapeseed yield data and parameter estimates are presented in Fig. 3. A multiple regression was performed based on the yield as the dependent variable and physiological traits as the independent variable.

Y = -21+0.32 (silique length)+ 0.045(100 seed weight)+ 0.13 (seeds per silique)

DISCUSSION

Present results showed that with increasing drought stress levels, SPAD meter readings were decreased. Ommen *et al*. (1999) reported that there was a close relationship between the SPAD meter readings and total chlorophyll concentrations (obtained from leaf extracts) for wheat under water stress. Based on these results, the SPAD meter can provide a quick estimation of extractable chlorophyll in rapeseed leaves. Ommen *et al*. (1999) also reported that, leaf chlorophyll content decreased under drought stress. Chlorophyll content is shown to be a precise indication of plant stress (Bauerle *et al*., 2004). Results of the current study indicated that, drought stress caused decreases in A, gs and LA values. It is clear that under drought stress, plants may minimize water loss by closure of their stomata, reduce the leaf area expansion and finally, lose their leaf area through leaf abscission and/or senescence. These results are in agreement with those of Massacci *et al*. (2008) in regard to A and g_s for LA. Multiple regression based on physiological traits showed that silique length and number of seeds per silique had significant ($p \leq 0.01$) effect on the yield then the traits can be considered as selection criteria.

Present results indicated that g_s decreases with leaves aging. This is in agreement with results reported by Siddique *et al*. (1999) who reported that g_s was increased with leaf age in wheat leaves. The strong relationship between A and g_s at both growth stages revealed that, reduction in A under drought stress, was regulated mostly by stomatal factors rather than non-stomatal closure. Drought stress also significantly decreased the C_i both at vegetative and flowering stages.

There was a strong correlation between g_s and seed yield of rapeseed cultivars. This is in agreement with those of Monneveux *et al*. (2006). Based on these results, it can be concluded that, g_s may be an appropriate trait for selecting cultivars with high yield potential. Bingcheng *et al*. (2006) in a study on three grasses reported similar results; however, Ricciardi *et al*. (2001) in a study on response of bean (*Phaseolus vulgaris*) genotypes to drought stress, reported that g_s was not a proper trait for selection, compared with genotype sensitivity indices. Based on present results, it can be concluded that SPAD meter readings is a simple and rapid method for evaluation of non-stomatal limiting factors induced by drought stress on photosynthesis. In general, Hayola 401 had the highest seed yield in both non-stressed and stressed treatments followed by Hayola 308, whereas RGS had the lowest seed yield among the cultivars. Hayola 401 and Hayola 308 had the highest g_s in control (non-stress) and the lowest g_s in drought treatments whereas, Option and RGS were lowest in this regard. Information obtained in this study, may be useful for breeders to introduce suitable drought resistant rapeseed cultivars under arid conditions.

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