



SHORT COMMUNICATION

RESPONSE OF AVENA SPECIES LEAF PHOTOSYNTHESIS AND STOMATAL CONDUCTANCE TO WATER STRESS

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Effect of water stress on photosynthesis was evaluated in seven *Avena* species under pot culture environment. Imposed water stress decreased photosynthetic rates and stomatal conductance. *A. sativa* L. maintained higher photosynthetic rate, stomatal conductance and P_N/C_i ratio under water stress during vegetative and flowering stages of crop growth indicating its suitability for moisture stress environment as compared to other species. However, the reduction in photosynthetic rates was low in *A. brevis* followed by *A. strigosa* at vegetative stage and *A. abyssinica* followed by *A. strigosa* and *A. sativa* at flowering stage indicating their relative drought tolerance potential. Significant correlations were observed between P_N and stomatal conductance and P_N and leaf water potential indicating the interdependence of these traits.

Key words: *Avena* species, photosynthetic rate, stomatal conductance, stress tolerant

The decrease of net photosynthesis under water stress can be attributed to both stomatal and non-stomatal limitations (Shangguan *et al.* 1999). The stomatal closure (Hamidou *et al.* 2007) under water stress is one of the most important factors affecting photosynthesis. Non-stomatal photosynthesis limitations have been attributed to the reduced carboxylation efficiency or by the direct inhibition of photosynthetic enzymes like Rubisco (Cornic *et al.* 1992, Haupt-Herting and Fock 2000, Kanechi *et al.* 1995) or ATP synthase (Nogues and Baker 2000) or to the inhibited functional activity of Photosystem 2 (PS II). Many studies proved that gas exchange decreased under drought stress (Li 2000, Yin *et al.* 2004, Zhang *et al.* 2004). Drought stress is an important environmental factor inhibiting plant growth and productivity (Li *et al.* 2000, Li and wang 2003). Oat is one of the major fodder crops to be grown world widely in diverse of environment and there is

urgent need to identify the elite genotypes for water stress situation. Understanding oat species and varieties to drought response may allow the selection of drought tolerant genotypes which can be used in improvement programme.

Seed of seven oat species (*viz.* *Avena strigosa* Schreb. (IG 03-543), *Avena brevis* Roth. (IG 03-471), *Avena vaviloviana* (Malzev) Mordv. (IG 03-548), *Avena abyssinica* Hochst. (IG 03-456), *Avena sativa* L. (JHO 822), *Avena marocana* Gand. (IG 03-486) and *Avena sterilis* L. (IG 03-529-1)) were sown in porcelain pots (30 x 33 cm) containing garden soil at pot culture experimental site of IGFRI, Jhansi, India (25°27'N, 78°35'E, 275 m a.s.l.) during November to April, 2006-07. The soil was clay loam in texture, neutral in reaction (pH 6.57). The available nitrogen, phosphorus and potassium were 23.62 g m⁻², 1.36 g (P) m⁻² and 27.92 g

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(K₂O) m⁻², respectively. The mean maximum and minimum temperature were 29.48 °C and 11.85°C. The photosynthetically active-radiation (PAR) ranged from 1000 to 1580 μmol m⁻² s⁻¹ during the growth period. After uniform germination three plants in each pot were maintained. After 15 days of germination one set of pot was kept under stress and another set of pots was watered regularly in three replications. The water stress was created by withholding of irrigation at vegetative and flowering stage of crop growth. After extreme stress, when wilting of leaves started, plants were re-watered. The crop was grown as per recommended agronomical practices. Rate of photosynthesis, stomatal conductance and intercellular CO₂ concentration of fully expanded leaf (2nd leaf from the top) was measured by using portable photosynthesis system (Model LI-6200, LICOR-Lincoln, USA) at 11-12 h on a clear sky day. The leaf temperature was measured by thermocouple of leaf chamber which attached at the lower surface of leaf during gas exchange measurement. A ratio of P_N/C_i (carboxylation efficiency) was also calculated. Leaf water potential was measured at the time of gas

exchange measurement. Leaf discs was cut from the second fully expanded leaves and kept in a C-52 sample chamber with the Thermocouple psychrometer connected with HR33T Dew point microvolt meter (Wescor-logan Inc. USA). Nine leaves per replication were measured for each parameter. All the observations were recorded at vegetative (at maximum plant height) and 50% flowering stages.

Different species of *Avena* responded differently to the water stress with respect to photosynthesis (P_N) and stomatal conductance (gs) at vegetative and flowering stages of crop growth (Table 1). The data revealed that *A. sativa* maintained higher rate of P_N at vegetative and flowering stages under stress and control exhibiting its suitability for diverse environmental conditions. Stress induced reduction in at both the stages as compared to control. However, the extent of reduction was lower in *A. brevis* followed by *A. strigosa* at vegetative stage and *A. abyssinica* followed by *A. strigosa* and *A. sativa* at flowering stage also indicating their relative drought tolerance. All the species showed higher P_N under control

Table 1. Rate of photosynthesis (P_N), stomatal conductance (gs) and fodder weight (g/plant) of oat species in response to water stress at vegetative and flowering stages of crop growth.

Species	Photosynthesis [μmol(CO ₂) m ⁻² s ⁻¹]				Stomatal conductance [mmole m ⁻² s ⁻¹]				Fodder weight (g/plant)			
	Vegetative		Flowering		Vegetative		Flowering		Vegetative		Flowering	
	Control	Stress	Control	Stress	Control	Stress	Control	Stress	Control	Stress	Control	Stress
	Control	Stress	Control	Stress	Control	Stress	Control	Stress	Control	Stress	Control	Stress
<i>A.strigosa</i>	24.00	13.71	25.56	14.80	0.523	0.217	0.669	0.324	22.41	11.00	147.32	47.85
<i>A.brevis</i>	20.02	13.06	27.16	12.76	0.344	0.187	0.632	0.261	31.63	11.48	80.12	49.96
<i>A.vaviloviava</i>	26.17	12.88	28.78	13.16	0.636	0.215	0.742	0.342	22.44	9.42	89.88	36.31
<i>A.abysinica</i>	22.91	10.46	19.47	12.95	0.493	0.192	0.564	0.264	22.72	8.25	55.65	41.62
<i>A.sativa</i>	27.97	14.12	28.35	16.37	0.637	0.258	0.864	0.456	21.06	10.71	163.22	80.45
<i>A.marocana</i>	21.32	11.16	24.61	13.21	0.564	0.219	0.712	0.432	23.67	8.09	72.27	50.85
<i>A.sterilis</i>	19.62	9.42	22.42	10.69	0.514	0.202	0.676	0.324	21.41	10.50	185.30	123.27
CD at 5%												
Species (S)	1.68		0.79		0.06		0.03		5.598		20.148	
Treatment (T)	0.90		0.42		0.03		0.01		3.463		11.285	
S X T	2.38		1.12		0.08		0.04		7.916		28.493	

and water stress at flowering stage of crop growth as compared to vegetative stages. The g_s was also reduced significantly under water stress as imposed at vegetative and flowering stages (Table 1). *A. sativa* had the highest g_s at vegetative and flowering stages under water stress followed by *A. marocana*. The reduction in g_s was low in *A. brevis* at vegetative stage and *A. marocana* at flowering stage as compared to other species tested.

Leaf temperature increased between 2.52°C to 2.70°C when the plants were subjected to water stress. The variation in leaf temperature is species dependent (Bhatt *et al.* 1991) and also depend on the rate of transpiration. The intercellular CO₂ concentration (C_i) increased by 5 to 28% at vegetative stage and 10 to 49% at flowering stage under water stress. Our results regarding the effect of drought stress on C_i were in agreement with Kicheva *et al.* (1994). The P_N/C_i ratio which indicates the carboxylation efficiency (Farquhar and Sharkey 1982) of stressed plants decreased significantly (Fig. 1). The P_N/C_i ratio decreased under stress at both the stages. However, *A. sativa* maintained higher ratio under stress as compared to other species. Under longterm stress environment, *A. sterilis* and *A. sativa* produced higher biomass as recorded at 50% flowering stage (Table 1).

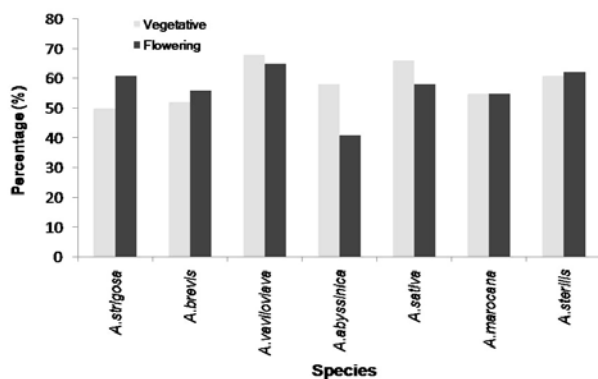


Fig. 1. Percentage of control of P_N/C_i in oat species at vegetative and flowering stages of crop growth.

Reduction in P_N in stressed leaves may be due to stomatal closure (Quick *et al.* 1989) as also evidenced by significant positive correlation between P_N and g_s ($r^2=0.8837$). The significant decrease in P_N of all the species and increase in leaf temperature under stress

indicates that there is partial closing of stomata to minimize the water loss as also reported by Hamidou *et al.* (2007) and Souza *et al.* (2004). Species difference in P_N and g_s under control and stress conditions exist in our results and having agreement with Li (2000), Yin *et al.* (2004), Zhang *et al.* (2004) in other crops. The increase in C_i under stressed environment indicates the poor carboxylation efficiency may be due to the less availability of Rubisco for CO₂ fixation. Which suggests photosynthesis is governed by both stomatal and non stomatal attributes. The P_N of the species changed with change in leaf water potential (ψ) due to the water stress. Under water stress there was a dramatic decline in P_N and accordingly the water potential decreased as evidenced by significant correlation between P_N and ψ at both the stages of crop growth (Fig. 2).

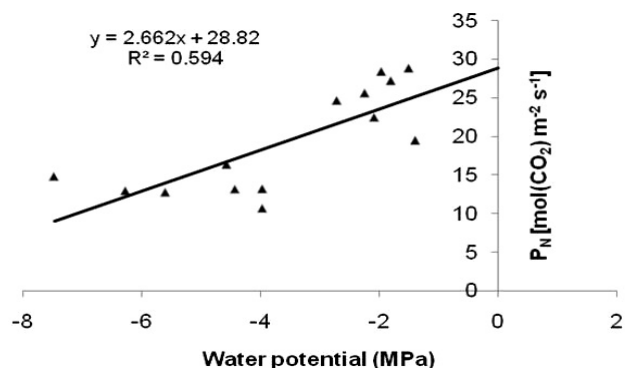


Fig. 2. Relationship between photosynthetic rate and stomatal conductance (A) and photosynthetic rate and leaf water potential (B).

In conclusion the results revealed that photosynthetic rate (P_N) and stomatal conductance (g_s) were affected by water stress but variation exists among the species. *A. sativa* maintained higher P_N and g_s under water stress indicating its drought tolerance potential. Furthermore, the magnitude of reduction in P_N was also observed lower in *A. brevis*, *A. strigosa* and *A. abyssinica* under water stress indicating their potential for further oat improvement programme.

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REFERENCES

- Bhatt, R.K., Misra, L.P. and Pathak, P.S. (1991). Diurnal variation in transpiration and energy exchange in some tree species from semi- arid region. *Indian J. Range Mgmt. Agroforestry* **12**: 79-84.
- Cornic, G., Ghashghaie, J., Genty, B. and Bariantais, J.M. (1992). Leaf photosynthesis is resistant to a mild drought stress. *Photosynthetica* **27**: 295-300.
- Farquhar, G.D. and Sharkey, T.D. (1982). Stomatal conductance and photosynthesis. *Annual Review Plant Physiology* **33**: 317-345.
- Hamidou, F., Zombre, G. and Braconnier, S. (2007). Physiological and Biochemical Response of Cowpea Genotypes to Water Stress under Glasshouse and Field Conditions. *J. Agron. Crop Sci.* **193**: 229-237.
- Haupt-Herting, S. and Fock, H.P. (2000). Exchange of oxygen and its role in energy dissipation during drought stress in tomato plants. *Physiol. Plantarum* **110**: 489-495.
- Kanechi, M., Kunitomo, E., Inagaki, N. and Maekawa, S. (1995). Water stress effects on ribulose-1,5-bisphosphate carboxylase and its relationship to photosynthesis in sun flower leaves. In: Mathis, M. (ed.): *Photosynthesis: from light to biosphere*. Vol. IV., pp. 597-600, Kluwer Academic Publisher, Dordrecht-London.
- Kicheva, M.I., Tsonev, T.D. and Popova, L.P. (1994). Stomatal and non-stomatal limitations to photosynthesis in two wheat cultivars subjected to water stress. *Photosynthetica* **30**: 107-116.
- Li, C. (2000). Population differences in water-use efficiency of *Eucalyptus microtheca* seedlings under different watering regimes. *Physiol. Plantarum* **108**: 134-139.
- Li, C. and Wang, K. (2003). Differences in drought responses of three contrasting *Eucalyptus microtheca* F. Muell. Populations. *Forest. Ecol. Management* **179**: 377-385.
- Nogues, S. and Baker, N.R. (2000). Effects of drought on photosynthesis in Mediterranean plants grown under enhanced UV-B radiation. *J. Exp. Bot.* **51**: 1309-1317.
- Quick, P., Siegl, G., Nauhaus, E., Feil, R. and Stitt, M. (1989). Short term water stress leads to stimulation of sucrose synthesis by activating sucrose-phosphate synthase. *Planta* **177**: 535-546.
- Shangguan, Z., Shao, M. and Dyckmans., J. (1999). Interaction of osmotic adjustment and photosynthesis in winter wheat under soil drought. *J. Plant Physiol.* **154**: 753-758.
- Souza, R.P., Machado, E.C., Silva, J.A.B., Lagoa, A.M.M.A. and Silveira, J.A.G. (2004). Photosynthetic gas exchange, chlorophyll fluorescence and some associated metabolic changes in cowpea (*Vigna unguiculata*) during water stress and recovery. *Environ. Exp. Bot.* **51**: 45-56.
- Yin, C., Wang, X., Duan, R., Zhu, Y., Li, C. (2005a). Early growth, dry matter allocation and water use efficiency of two sympatric *Populus* species as affected by water stress. *Environ. Exp. Bot.* **53**: 315-322.
- Zhang, X., Zang, R. and Li, C. (2004). Population differences in physiological and morphological adaptations of *populus davidiana* seedlings in response to progressive drought stress. *Plant Sci.* **166**: 791-797.