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BRIEF COMMUNICATION

Effect of soil moisture on the gas exchange of *Changium smyrnioides* and *Anthriscus sylvestris*

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Abstract

The effect of soil moisture on gas exchange and growth of an endangered species, *Changium smyrnioides*, was compared with a non-endangered species, *Anthriscus sylvestris*. The two species belong to the same family *Umbellaceae*. With the decrease of soil moisture, the net photosynthetic rate (P_N) and transpiration rate (E) decreased, while water use efficiency (WUE) increased. P_N and WUE of *C. smyrnioides* were lower than those of *A. sylvestris*, whereas E was higher than that of *A. sylvestris*. The biomass, leaf mass ratio (LMR) and leaf area ratio (LAR) of *C. smyrnioides* were lower than those of *A. sylvestris*. Under drought, biomass, LMR and LAR of *C. smyrnioides* decreased more steeply than those of *A. sylvestris*, whereas specific root length (SRL) of *C. smyrnioides* was higher, compared to that of *A. sylvestris*. The present study indicated that *C. smyrnioides* accumulated less biomass, and directed more biomass to roots than *A. sylvestris*.

Additional key words: growth analysis, photosynthesis, physiological traits, structural traits, transpiration, water use efficiency.

Changium smyrnioides Wolff, a monotypic species of the family *Umbellaceae* has a narrow distribution and has been described as an endangered species (Chang *et al.* 2002). *Anthriscus sylvestris* (L.) Hoffm. belongs to the same family and has a similar life form. It has a wider distributing area than *C. smyrnioides* and it is not endangered. In the fields, *C. smyrnioides* can be found from catchments to dry mountain places, while *A. sylvestris* are only found in catchments and/or beside mountain rivulet. It is unknown at present, what factors leads to the differences in distribution areas between the two species. Causes for the endangerment of *C. smyrnioides* remains to be elucidated.

Water stress causes changes in biomass accumulation, growth rate and many other physiological/structural traits (Arora *et al.* 2001, Barathi *et al.* 2001). These traits are important as it can contribute to the capability of competitiveness, ecological distribution (Bell 1999) and existence of plants (Fenner 1978, Gross 1984, Larcher 1994, Garg *et al.* 2001). In order to find out soil water demand of the two species, carbon accumulation in terms of photosynthesis and other ecophysiological/structural traits was studied. From the results of the experiment, niche differences of the two species are analyzed and the relationship between water niche of *C. smyrnioides* and its endangerment is discussed.

Research was conducted at the plantation of Zhejiang University in Hangzhou, eastern China (120 °10' E, 30° 15' N). *C. smyrnioides* and *A. sylvestris* seeds were germinated in mid-January and mid-February 2002 and

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Abbreviations: AW_{100} - relative soil water contents at 100 % soil water holding capacity; AW_{50} - relative soil water content ranging from 50 to 100 %; AW_{20} - relative soil water content ranging from 20 to 100 %; E - transpiration rate; LAR - leaf area ratio; LMR - leaf mass ratio; P_N - net photosynthetic rate of leaf; P_{Nmean} - diurnal mean photosynthetic rate per individual; PAR - photosynthetic active radiation; RH - air relative humidity; RWC_s - relative soil water content; SRL - specific root length; T_a - air temperature; T_l - leaf temperature; WUE - water use efficiency (P_N/E).

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were then cultivated in pots (height 14.5 cm, rim diameter 17.5 cm) for two weeks. All treatments began in early March 2002 and were carried out in a glasshouse. There were three different soil moisture treatments. For the moist treatment (AW_{100}), soil water content was kept near 100 % water holding capacity; for the moderate moist treatment (AW_{50}) plants were watered whenever the relative soil water content (RWC_s) dropped to 50 %, and for the drought treatment (AW_{20}) plants were watered whenever the RWC_s dropped to 20 %.

Measurements of net photosynthetic rate (P_N) and transpiration rate (E) were carried out every hour in triplicates from 06:30 to 18:30 on clear days in the beginning of May. P_N was measured using the CO_2 analyzer (*GHX305*, Beijing, China-German cooperation) in a close system. Diurnal mean photosynthetic rate per individual (P_{Nmean}) was calculated by the average of P_N at every hour multiplying LAR. E of whole shoots was measured by weighting whole pots whose upper surface were enclosed by plastic film for prevention of soil evaporation: $E = (W_t - W_{t+1})/A$. Where, W_t is the initial fresh mass of pots, W_{t+1} is the fresh mass at next time, and A is the total area of the leaves in pots. Water use efficiency (WUE) was calculated as P_N/E. Photosynthetically active radiation (PAR) above the leaf, air temperature (T_a) and relative humidity (RH) were measured simultaneously with P_N using a *Li-1600* portable steady porometer (*Li-Cor*, Lincoln, NE, USA). The stomatal conductance (g_s) could not be measured because of the fragmental leaves of the two species. Leaf temperature (T_l) was measured simultaneously during P_N measurements (*RAYST3LX*, Santa Cruz, USA). In March 2002, three individuals of each species were harvested from the three replications pots. All leaf area was measured using a portable area meter. Then all samples were dried in an oven at 80 °C for at least 72 h. Leaf area per unit leaf mass (specific leaf area, SLA), leaf area per unit of total mass (leaf area ratio, LAR) and leaf mass per unit of total mass (leaf mass ratio, LMR) and root length per unit of root mass (specific root length, SRL) were determined (Hunt 1978). Differences between the traits were statistically analyzed with *ANOVA* in *SPSS 8.0*.

For *C. smyrnioides* and *A. sylvestris*, P_N in the morning was greater than the P_N in the afternoon, and P_N decreases as soil water content decreases (Fig. 1), the differences among the treatments in morning was greater than in the afternoon. The E of *A. sylvestris* reached maximum earlier than that of *C. smyrnioides*. For *C. smyrnioides*, E at AW_{50} was similar to E at AW_{100}, while E of *A. sylvestris* at AW_{50} was similar to AW_{20}. The WUE of *C. smyrnioides* was lower than that of *A. sylvestris* in the morning. The diurnal mean P_N and WUE of *C. smyrnioides* were lower than those of *A. sylvestris* in all three treatments, while E was higher than that of *A. sylvestris*. A decrease in soil water leads to a decrease in P_N and E, while an elevation in WUE.

Multiple regression analysis showed that P_N of *C. smyrnioides* (Y_{1P}) and *A. sylvestris* (Y_{2P}) increased linearly with PAR and RWC and E of *C. smyrnioides* (Y_{1E}) with T, RH and RWC:

$Y_{1P} = 1.62 + 0.0066\ \mathrm{PAR} + 0.018\ \mathrm{RWC}$
$F = 49.08\ (P < 0.001)$

$Y_{2P} = 2.40 + 0.0078\ \mathrm{PAR} + 0.015\ \mathrm{RWC}$
$F = 43.67\ (P < 0.001)$

$Y_{1E} = -27.838 + 0.807\ \mathrm{T} + 0.174\ \mathrm{RH} + 0.0126\ \mathrm{RWC}$
$F = 15.82\ (P < 0.001)$

However, the effect of soil water content on *E* of *A. sylvestris* was not significant. P_{Nmean} and LAR of *C. smyrnioides* were much lower than those of *A. sylvestris* in all soil water status (Table 1). LMR of *C. smyrnioides* in the treatments AW_{20}, AW_{50} and AW_{100} were 77, 83 and 86 % of that of *A. sylvestris*, respectively. The LMR of *C. smyrnioides* decreased more quickly than *A. sylvestris* with soil mositure decrease. This suggested that *C. smyrnioides* allocated more mass to underground parts compared with *A. sylvestris*, especially under drought.

C. smyrniodies was more capable in elongating roots in drought environments, as indicated by the greater SRL in *C. smyrnioides* compared to *A. sylvestris*. The SRL of *C. smyrnioides* in treatments AW_{20}, AW_{50} and AW_{100} was 6.38, 4.83 and 3.47 time greater than that of *A. sylvestris*, respectively. The difference of root elongation growth between *C. smyrnioides* and *A. sylvestris* was more prominent at low soil water content.

The observed difference in carbon accumulation is thought to account for the biomass differences between the two species. The biomass of *C. smyrnioides* was 11, 15 and 19 % of that of *A. sylvestris* in AW_{20}, AW_{50} and AW_{100} respectively. The total biomass of *C. smyrnioides* was lower than that of *A. sylvestris* and the difference was greatest at drought. The biomass of *C. smyrnioides* differed significantly between the AW_{100} and AW_{50}, while for *A. sylvestris* there was significant difference only between the AW_{100} and AW_{20} treatments.

Previous studies have provided evidences that a low growth rate may be advantageous in seedling establishment under competitive situations (Fenner 1978, Gross 1984). Generally speaking, species of the *Umbelliferae* are characterized by low growth rate, including *A. sylvestris* (Grime *et al.* 1988). However *C. smyrnioides* grows even slower than *A. sylvestris*, and the low amount of photosynthates is direct to the root, especially under drought. Longer root anable *C. smyrnioides* survive in drought habitats, as water from different soil layers can absorb (Bell 1999). *A. sylvestris* has more shallow roots compared to *C. smyrnioides*, which may explains its inability to grow in drought habitats. After dormancy, there was only a 10 % mortality of *C. smyrnioides* in all treatments, but *A. sylvestris* had 80, 40, 30 % mortality in AW_{20}, AW_{50}, AW_{100}, respectively. The ability to alter growth pattern

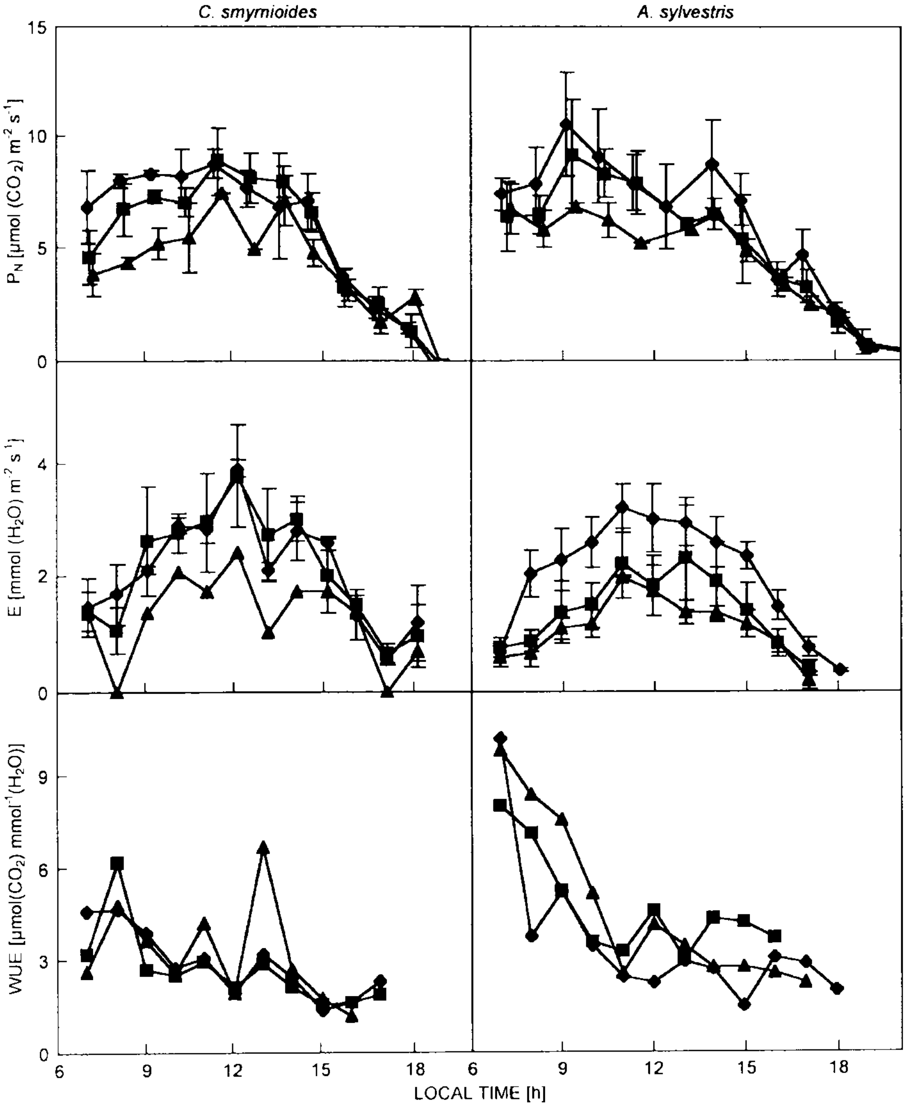

Fig. 1. Diurnal variations of the net photosynthetic rate (P_N), transpiration rate (E) and water use efficiency (WUE) of *Changium smyrnioides* and *Anthriscus sylvestris* in AW_{20} (*triangles*), AW_{50} (*squares*) and AW_{100} (*diamond*) soil water treatment.

Table 1. Specific leaf area (SLA), leaf area ratio (LAR), leaf mass ratio (LMR), specific root length (SRL), biomass (B) and diurnal mean photosynthetic rate (P_{Nmean}) of *Changium smyrnioides* and *Anthriscus sylvestris* in three soil water treatments AW_{100}, AW_{50} and AW_{20}. Means ± SE (*n* = 17 - 35 for SLA, *n* = 6 - 10 for other traits). Different letters express significantly different results between water treatments (ns - no significant).

Plants	Treatments	SLA [dm^2 g^{-1}]	LAR [dm^2 g^{-1}]	LMR [g g^{-1}]	SRL [dm g^{-1}]	B [g plant^{-1}]	P_N [μmol m^{-2} s^{-1}]
C. smyrnioides	AW_{100}	2.04 ± 0.52^{a}	0.55 ± 0.16^{a}	0.25 ± 0.09^{a}	1.20 ± 0.56^{a}	0.78 ± 0.39^{a}	0.0287 ± 0.0014^{a}
	AW_{50}	2.41 ± 0.75^{a}	0.72 ± 0.26^{a}	0.30 ± 0.14^{a}	3.08 ± 1.31^{b}	0.42 ± 0.20^{b}	0.0164 ± 0.0008^{b}
	AW_{20}	2.96 ± 1.25^{a}	0.69 ± 0.34^{a}	0.24 ± 0.12^{a}	4.33 ± 3.10^{b}	0.24 ± 0.14^{b}	0.0062 ± 0.0002^{c}
A. sylvestris	AW_{100}	2.29 ± 0.56^{a}	0.64 ± 0.08^{a}	0.29 ± 0.06^{a}	0.35 ± 0.15^{a}	4.10 ± 1.40^{a}	0.1634 ± 0.0060^{a}
	AW_{50}	2.61 ± 0.99^{a}	0.84 ± 0.16^{b}	0.36 ± 0.08^{a}	0.64 ± 0.28^{ab}	2.71 ± 1.04^{ab}	0.1236 ± 0.0050^{b}
	AW_{20}	2.35 ± 0.67^{a}	0.76 ± 0.14^{ab}	0.31 ± 0.07^{a}	0.68 ± 0.16^{b}	2.26 ± 0.43^{b}	0.0798 ± 0.0004^{c}
Difference		ns	ns	ns	< 0.001	< 0.01	< 0.01

(to elongate roots) may contribute to *C. smyrnioides* wide distribution from drought to wet habitats, while *A. sylvestris* with low plasticity in root elongation can only grow in wet environment. Therefore, it is concluded that carbon accumulation rate and root length phenotypic plasticity are not the factors causing the endangerment of *C. smyrnioides*. The reason that *C. smyrnioides* has become endangered is the increasing human disturbances, such as digging the plant for medicinal use and deforestation, and the low carbon accumulation of this species.

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