Leaf angle as an Indicator for Gauging Water Stress in Sunflowers

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ABSTRACT

A preliminary study was carried out to monitor the effect of water stress on the leaf stature of sunflower in relation to its leaf angle (LA: angle where the petiole joins the main stem). Plants were grown in the glasshouse under optimal conditions of water supply until the onset of flowering and at this stage they were subjected to different soil moisture levels. LA was monitored ten days after the introduction of moisture treatment and the plants were photographed to illustrate the changes. Relative water content (RWC) and leaf water potential (LWP) of the upper, middle and lower leaves were measured to quantify plant water status and the values were matched with LAs as illustrated on the photographic standard. Altering plant water status has resulted in clearly visible changes in LA with the associated changes in leaf RWC and LWP. Development of a photographic standard of LA may prove beneficial in irrigation scheduling of crops.

Key words: Leaf Angle, Relative Water Content, Leaf Water Potential. Photographic Standards

INTRODUCTION

Water status in plants is governed by soil, plant and atmospheric conditions. An imbalance in any of these components may lead to some form of modification of plant growth characteristics. These characteristics are likely to be manifested by different plant organs, particularly the leaves (Hsiao, 1990).

Sunflower leaves are produced in opposite alternate pairs, and after five opposite pairs a whorled form of alternate phyllotaxy develops. Leaves on single stemmed plants may vary in number from 8 to 30 or more. Low plant water potential is known to cause reduction in both leaf number and area of individual leaves (Merrien, 1992; Parameswaran, 1992).

The orientation of sunflower leaves and petioles changes as the plant grows. On emerging from the terminal bud, the petiole is almost vertical until it is about a centimetre long. As elongation continues, the petiole curves away from the stem forming an angle between the two. The blade is horizontal throughout early development and rapid elongation, but begins to droop under water stress, thus resulting in changes in leaf angle.

Quantification of plant water stress is usually measured by leaf water potential, or relative water content. Under conditions of acute water shortage some plants can reduce their rate of water loss to a very low level by altering morphological features and/or physiological mechanisms, so that a relatively high water potential is maintained within their tissues (Hsiao,1990; Kirkham,1990). The adaptive xeromorphic features (Jones and Zur, 1984) include thick cuticles, sunken stomata, rolling of leaves, daytime closure of stomata and high reflectance etc. and such plants are often referred to as water stress avoiders.

Among all morphological characteristics, expansive growth of leaves and stems is the one most sensitive to water stress in sunflower (Sadras, et.al., 1993). Once plant water content is lowered, leaf turgor diminishes very rapidly inhibiting leaf growth.

The aim of this experiment was to monitor the effect of water stress on leaf characteristics in relation to the angle of the petiole, and to examine its usefulness as an indicator for gauging water stress in sunflowers.

MATERIALS AND METHODS

The experiment was conducted at the Victorian College of Agriculture and Horticulture, Dookie Campus in 1995. Plants were grown in pots in the glasshouse. Three seeds of sunflower cultivar Hysun 25 were sown per pot initially; when emerged (14 days after sowing) plants were thinned to one per pot.

Plants were regularly watered until the onset of flowering. From this point, three water treatments based on the available water content of soil were introduced: low water (W_1), medium water (W_2) and unrestricted water (W_3) respectively. The experiment was arranged in a completely randomised design with 12 replications in each case (36 pots in total).

Upon clear signs of water stress the leaf angle at the junction of the petiole and stem (clockwise or anti-clockwise on alternate leaves) was measured using a protractor. Once the leaf angles were measured, photographs were taken to record the visible symptoms of stress. Soon after, the leaves from upper, middle and lower positions on the stem were severed and used for LWP and RWC measurements using methods as outlined by Parameswaran, Graham and Aspinall 1984.

Data was analysed using analysis of variance. Statistical correlations between LA and water status measurements (RWC and LWP) were calculated to examine the usefulness of LA as an indicator of plant water stress..

RESULTS

As might be expected, both RWC and LWP measurements were significantly influenced by the imposed water stress treatments (Table 1). In general, the measured values were lower than anticipated, particularly in treatments W_2 and W_3. This may have been due to the stage of growth of the plants, and the particular time (midday at full radiation) when the measurements were carried out.

The changes in RWC and LWP between leaves at different positions of the plant, and within a particular level of stress, were small and proved to be not significant. Generally, however, values increased progressively from upper to lower leaves.

Table 1 **RWC, LWP and LA measured on upper, middle and lower leaves**

Water Status	Leaf Position	RWC %	LWP MPa	LA°
W_1				
	UL	47	-1.94	51
	ML	54	-1.87	54
	LL	56	-1.80	61
Mean		**52 a**	**- 1.87 d**	**55 g**
W_2				
	UL	70	-1.38	31
	ML	74	-1.29	34
	LL	79	-1.14	35
Mean		**74 b**	**-1.27 e**	**33 h**
W_3				
	UL	76	-1.20	29
	ML	79	-1.13	33
	LL	85	- 0.93	34
Mean		**80 c**	**-1.09 f**	**32 h**

UL: Upper Leaves; ML: Middle Leaves; LL: Lower Leaves
Values are significant at $p < 0.001$. Mean values in each column followed by same letters are not statistically significant

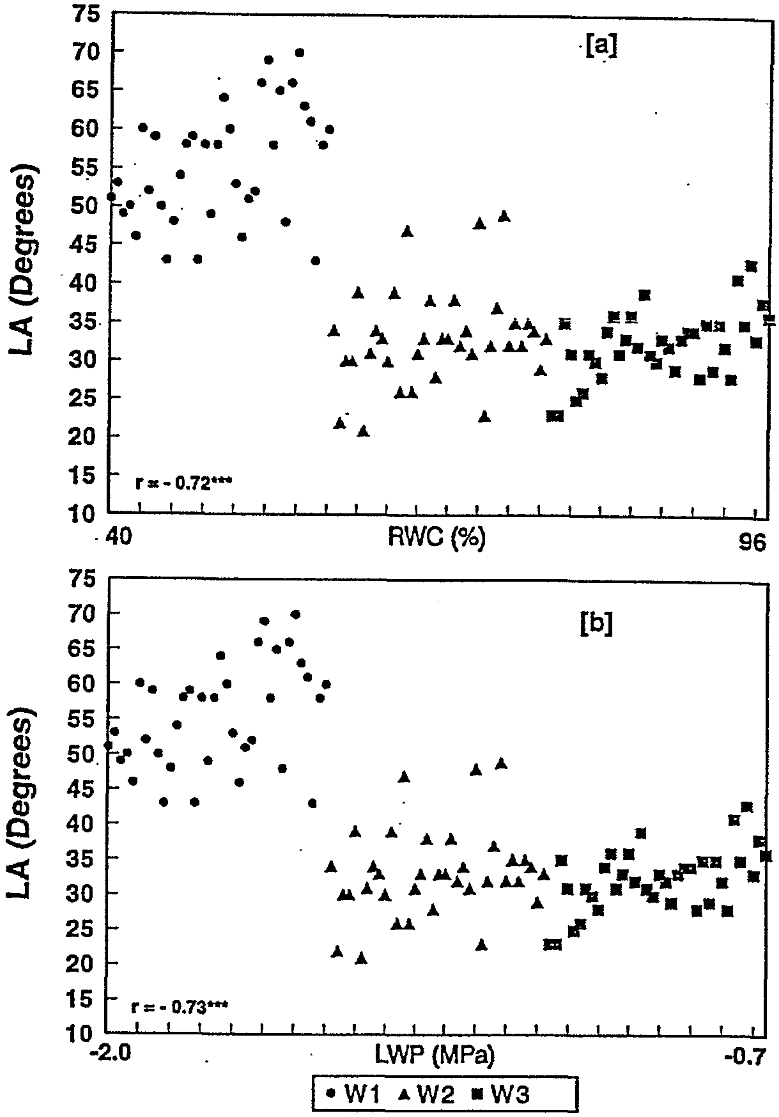
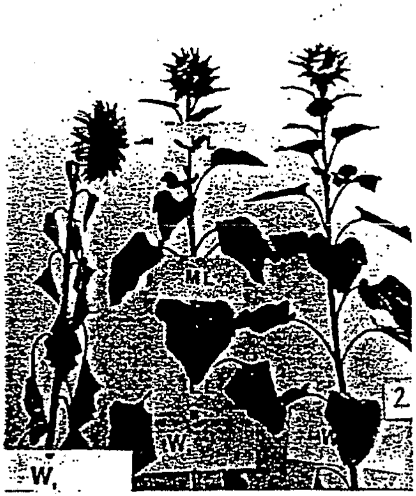
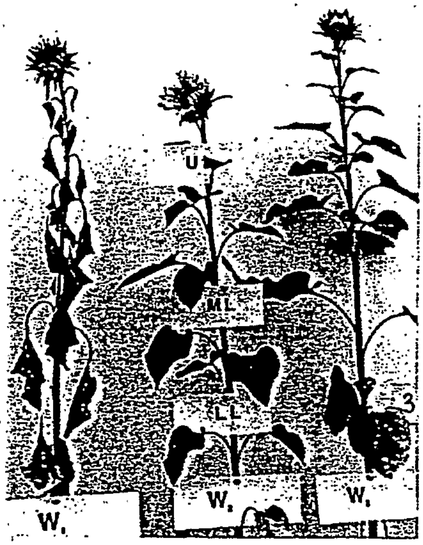


Fig. 1 Relationship between (a) RWC and LA, and (b) LWP and LA as affected by water stress

(a)	W1 UL	W1 ML	W1 LL	W2 UL	W2 ML	W2 LL	W3 UL	W3 ML	W3 LL
RWC (%)	54	56	60	61	62	66	80	85	93
LWP MPa (-)	2.1	1.8	1.9	1.3	1.2	1.4	0.8	0.9	1.0
LA°	51	58	66	34	47	48	23	33	28



(b)	W1 UL	W1 ML	W1 LL	W2 UL	W2 ML	W2 LL	W3 UL	W3 ML	W3 LL
RWC (%)	41	46	48	65	68	73	80	82	86
LWP MPa (-)	2.2	2.1	2.2	1.5	1.4	1.2	1.1	1.0	0.9
LA°	49	43	58	60	58	66	28	30	28



(c)	W1 UL	W1 ML	W1 LL	W2 UL	W2 ML	W2 LL	W3 UL	W3 ML	W3 LL
RWC (%)	42	49	52	78	82	90	76	75	85
LWP MPa (-)	2.1	2.0	1.9	1.2	1.0	0.8	1.2	1.2	1.0
LA°	50	53	61	31	33	35	34	33	33

(d)	W1 UL	W1 ML	W1 LL	W2 UL	W2 ML	W2 LL	W3 UL	W3 ML	W3 LL
RWC (%)	43	44	53	70	72	77	79	83	93
LWP MPa (-)	2.0	2.1	1.3	1.4	1.3	1.2	1.1	1.0	0.7
LA°	46	51	56	33	38	35	31	33	41

Fig 2. Photographic standards showing leaf angles of the upper, middle and lower leaves of sunflowers subjected to varying levels of plant water stress

Leaf angles were affected by plant water status, and increased progressively from W_3 treatment to W_1. Within this general trend however, lesser effects due to leaf positions were apparent. There was no significant difference between mean LA values of W_2 and W_3. However, compared with W_2 and W_3, the mean LA value of the W_1 treatment showed increases to the magnitude of approximately 40%. There was no significant interaction between the various water levels and leaf positions in relation to LAs.

The relationship between RWC, LWP and LA is shown in Fig. 1. Leaf angles were inversely related ($p < 0.001$) to changes in both measures of leaf water status. However, there was a tendency for LAs to remain relatively constant above 80% RWC, or correspondingly, an LWP of about - 1.20 MPa.

The standards developed using photographs (Fig. 2 a, b, c and d) show the wilting of sunflower leaves under different stress levels with associated changes in LA of upper, middle and lower leaves.

DISCUSSION AND CONCLUSION

The growth, development and water use of sunflower are closely related to its water status (Merrien, 1992). Similar to many other plants, sunflowers are also known to respond to morphological changes during stress (Connor and Jones,1985; Sadras et al., 1993) and thus regulate water status to survive drought conditions.

Expansive growth of leaves and stems in sunflower is known to be most sensitive to water stress (Sadras et al.,1993). Not only does leaf area decrease with water stress, leaf angles can also change, as has been demonstrated by this study. Increases in leaf angle may lead to reduced water flow to the blade and hence reductions in transpiration loss during stress conditions. Similar studies involving soybeans showed inversion of leaflets resulting from changes in leaf angles during stress, thus exposing the more reflective abaxial surface to reduce water loss (Oosterhuis, 1986).

Direct measurements such as RWC and LWP have often been used by researchers to determine the current water status in plants. These measurements are, however, considered to be time consuming and cumbersome for practical irrigation scheduling. As indicated by this study, leaf angle is closely related to RWC and LWP and it follows that plant water status in sunflowers may be inferred from measurements of changing leaf angles.

Leaf angle may thus prove beneficial as an easy and measurable indicator for scheduling irrigations in the field. Photographic standards illustrating leaf angles matched with related RWC or LWP values, may serve as an additional and easy-to-use reference tool. As was found in this study, LA measurements of leaves at various positions of the stem did not seem to alter relative to RWC and LWP measurements. With this in mind, the clearly visible top leaves of a plant can be used as a water stress indicator, where LAs can be measured with less difficulty.

In addition, top leaves provide an early indication of water stress, thereby improving crop water use efficiency.

ACKNOWLEDGMENTS: Appreciation is extended to Mr Ken Stuart of Pacific Seeds, Cobram, Victoria for providing Hysun 25 seeds, Mr Ian Stevens and Mrs Carmel Lancaster for technical assistance, Mr Neville Davey for preparing photographs and Mr Doug Maconachie for caring and managing plants in the glasshouse.

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