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# A Note on Methods Measuring the Internal Water Status in Leaves of Sunflower Plants (*Helianthus annuus* L.)

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## ABSTRACT

Leaf water content of the sunflower plants was estimated using Stocker's technique proposed in 1929 as well as Weatherley's equation developed in 1950. In the latter method entire leaves were used instead of leaf discs for determining relative turgidity (R.T.). Because of the objections raised against the use of the relative turgidity term, the relative water deficit (R.W.D.) was calculated as 100-R.T. Attempts were made to correlate the calculated values of R.W.D. with the values of water saturation deficit (W.S.D.) obtained by adapting Stocker's technique. Correlation (r) and regression (b) coefficients between R.W.D. and W.S.D. were found to be highly significant and reached unity ( +0.999 for r and +0.997 for b). Although modifications were introduced to Weatherley's technique, calculated water deficit was identical with that obtained by Stocker's method.

## INTRODUCTION

Limited resources of fresh water is the most important factor determining any successful cropping under the arid conditions of Libya. Efficient use and conservation of water become extremely desirable in this case. Any simple method and easy to practice with acceptable accuracy will suffice to provide an index for plant water status, as the lack of experienced and skilled workers is a major obstacle in this country. Therefore, the search for such method among the several techniques proposed in the literature (2,3,4) has led to two satisfactory methods. One of these was suggested as early as 1929 by Stocker from which leaf water deficit can be estimated. Accordingly, entire leaves or branches are collected from tested plants, immediately weighed, kept in a closed container with their petioles or bases in water until they reach equilibrium, reweighed and oven dried. The water saturation deficit is then estimated using these parameters. Many investigators (1,3) adapted this method in their work on plant water stress reasoning that it results in more accurate values of water deficit that not affected directly by changes in tissue dry weight.

The second method was proposed in 1950 by Weatherley (6) for measuring what was called 'relative turgidity', or 'relative water content' (2,4). For estimating relative turgidity, small discs (0.7 to 1.0 cm in diameter) are punched from leaves of tested plants and their fresh weight is determined, floated on water for several hours until full tur-

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gidity is reached, reweighed and finally oven dried. From these values, relative turgidity can be calculated. Application of this technique requires careful sampling of plant tissue to ensure satisfactory fresh weight. Furthermore, errors are possible in estimating turgid and dry weight of collected leaf discs. However, efforts were made for modifying this technique and to eliminate these difficulties (4). Compared with entire leaves, higher estimates of water deficit and lower turgidity are the main drawbacks of the leaf discs technique. On the other hand, it has advantage over Stocker's method as the time required for reaching full turgidity of leaf discs is shorter than with whole leaves.

The present paper deals with determining water deficit of entire leaves using the two equations proposed by Stocker and Weatherley and with correlating the yielded values.

## MATERIALS AND METHODS

Fully expanded leaves were collected from field grown Sunflower plants (*Helianthus annuus* L.) and kept in plastic bags for determination of fresh weight soon after cutting. Single leaves were put with their petioles in water in closed jars for 24 hours until saturation. Filter papers were used for removal of water over the petioles and surface of leaves before weighing. After determination of the leaf saturation weight, they were kept overnight in oven and finally, dry weight was obtained.

I. Water saturation deficit (W.S.D.) was calculated from Stocker's equation (3) as follows:

$$\text{W.S.D.} = \frac{\text{Saturated Wt.} - \text{Fresh Wt.}}{\text{Saturated Wt.} - \text{Dry wt.}} \times 100$$

II. Relative turgidity (R.T.) was calculated from Weatherley's equation (6) as follows:

$$\text{R.T.} = \frac{\text{Fresh Wt.} - \text{Dry wt.}}{\text{Saturated Wt.} - \text{Dry Wt.}} \times 100$$

III. Relative Water deficit (R.W.D.) was calculated as follows:

$$\text{R.W.D.} = 100 - \text{R.T.}$$

Correlation (r) and regression (b) coefficients between W.S.D. and R.W.D. were computed using the following equation (5):

$$r = \frac{S(XY) - \frac{(SX)(SY)}{n}}{\sqrt{S(X)^2 - \frac{(SX)^2}{n} \times S(Y)^2 - \frac{(SY)^2}{n}}}$$

$$b = \frac{S(XY) - \frac{(SX)\,(SY)}{n}}{S(X)^2 - \frac{(SX)^2}{n}}$$

Where:

r = correlation coefficient
b = regression coefficient
x = Water saturation deficit (W.S.D.) value
y = relative water deficit (R.W.D.) value
n = total number of samples
s = Sum

The regression line was computed as follows:

$$Y = \bar{y} + b(X - \bar{x})$$

Where:

$Y$ = predicted value of R.W.D. for a given value of $X$ = (W.S.D.)

$\bar{y}$ = mean of R.W.D.

$\bar{x}$ = mean of W.S.D.

$b$ = regression coefficient

## RESULTS AND DISCUSSION

Estimations of relative turgidity (R.T.) of the whole leaves using Weatherley's equation, relative water deficit (R.W.D.) calculated as 100-R.T., and water saturation deficit (W.S.D.) using Stocker's equation are presented in Table 1. From these data, it is clear that a linear relation exists between values of water deficit in leaves obtained by both equations. The correlation coefficient (r) between the calculated relative water deficit (R.W.D.) as 100-R.T. and the measured values of water saturation deficit (W.S.D.) was found to be highly significant and reached unity ($r = +0.999$). The coefficient of determination ($r^2$) of 0.998 indicates that almost any variation in the calculated values of R.W.D. is associated with variation in the measured values of W.S.D. Also, the regression of R.W.D. on W.S.D. is linear ($b = +0.997\%$).

The scatter diagram and the regression line of Fig. 1 show a clear linear relationship

Table 1 Comparison between relative turgidity (RT), relative water deficit (RWD) estimations by Weatherley method and determinations of water saturation deficit by Stocker technique using entire sunflower leaves.

| Sample | Relative turgidity (RT) % | Relative water deficit (RWD) 100-RT % | Water saturation deficit (WSD) % | Sample | Relative turgidity (RT) % | Relative water deficit (RWD) 100-RT % | Water saturation deficit (WSD) % |
|---|---|---|---|---|---|---|---|
| 1 | 79.1 | 20.9 | 20.9 | 23 | 79.7 | 20.3 | 20.3 |
| 2 | 81.2 | 18.8 | 18.8 | 24 | 77.4 | 22.6 | 22.6 |
| 3 | 77.8 | 22.2 | 22.2 | 25 | 70.8 | 29.2 | 29.2 |
| 4 | 80.3 | 19.7 | 19.8 | 26 | 74.8 | 25.2 | 25.2 |
| 5 | 81.0 | 19.0 | 19.1 | 27 | 81.1 | 18.9 | 20.7 |
| 6 | 85.6 | 14.4 | 14.4 | 28 | 80.0 | 20.0 | 20.0 |
| 7 | 81.6 | 18.4 | 18.4 | 29 | 88.9 | 11.1 | 11.1 |
| 8 | 82.5 | 17.5 | 17.5 | 30 | 80.6 | 19.4 | 19.4 |
| 9 | 87.1 | 12.9 | 12.9 | 31 | 71.7 | 28.3 | 28.8 |
| 10 | 86.9 | 13.1 | 13.0 | 32 | 74.2 | 25.8 | 25.8 |
| 11 | 82.0 | 18.0 | 18.0 | 33 | 72.9 | 27.1 | 28.6 |
| 12 | 74.4 | 25.6 | 25.6 | 34 | 63.8 | 36.2 | 36.2 |
| 13 | 77.9 | 22.1 | 22.1 | 35 | 56.9 | 43.1 | 43.1 |
| 14 | 76.9 | 23.1 | 23.1 | 36 | 65.2 | 34.8 | 34.8 |
| 15 | 79.9 | 20.1 | 20.1 | 37 | 74.4 | 25.6 | 25.6 |
| 16 | 82.1 | 17.9 | 17.9 | 38 | 66.9 | 33.1 | 33.2 |
| 17 | 87.9 | 12.1 | 12.1 | 39 | 69.4 | 30.6 | 30.7 |
| 18 | 85.4 | 14.6 | 14.6 | 40 | 74.5 | 25.5 | 25.5 |
| 19 | 82.2 | 17.8 | 17.8 | 41 | 66.0 | 34.0 | 34.0 |
| 20 | 85.7 | 14.3 | 14.3 | 42 | 66.9 | 33.1 | 33.1 |
| 21 | 85.8 | 14.2 | 14.2 | 43 | 65.5 | 34.5 | 34.5 |
| 22 | 76.6 | 23.4 | 23.4 | Average | 77.24 | 22.76 | 22.85 |

Correlation coefficient (r) between WSD and RWD = +0.999

Coefficient of determination ($r^2$) between WSD and RWD = +0.998

Regression coefficient (b) of RWD on WSD = +0.997 %

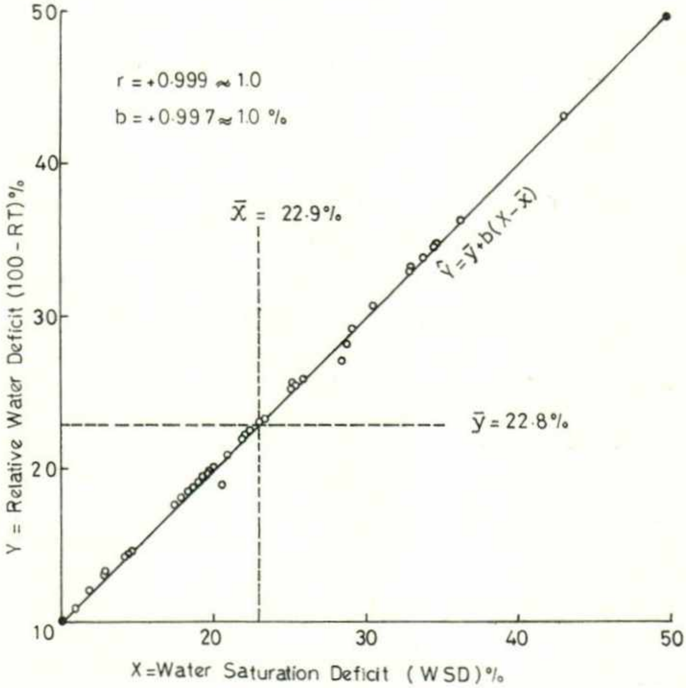


Fig. 1. A scatter diagram and the regression line showing the relationship between the relative water deficit (R.W.D.) and the water saturation deficit (W.S.D.).

between the R.W.D. as estimated from Weatherley's Equation and the W.S.D. obtained by Stocker's method. It is clear that no deviations exist between the computed regression line and the estimated values of R.W.D. and W.S.D.

From these data, it can be concluded that both equations proposed by Stocker and Weatherley for measuring the water status in plant tissue can yield more or less similar results provided that whole leaves are used. Furthermore, comparisons of both methods with different plant species and in addition to the technique of leaf discs seems desirable.

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