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A Quick Technique for Determining the Wettability of Leaves of *Arachis hypogaea* and Certain Other Species[1]

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ABSTRACT

A rapid and accurate technique for assessing the wettability of leaves of *Arachis hypogaea* L. and certain other species was developed. The method quantifies the retention of water on the surface when water is drained from around vertically immersed leaves at a constant rate. Although the relationship between mean contact angle measurements and water retained was not strictly linear, the correlation between the two variables was extrememly high, r = 0.997 (P = 0.001). This constant drainage technique can be used in the greenhouse and field and with some species does not require leaf detachment from the plant.

Key Words: *Arachis hypogaea* L., contact angle, leaf wettability, peanut rust, *Puccinia arachidis* Speg..

In an investigation of the relationship between the water repellency of peanut (*Arachis hypogaea* L.) leaves and their susceptibility to rust (caused by *Puiccinia arachidis* Speg.) (4) it was necessary to assess the wettability of many leaves within a short time period. The standard technique for determining the wettability of leaf surfaces is by making contact angle measurements (2, 9, 11, 13, 15). However, contact angles can vary on different areas of any one surface of a leaf and the means of several determinations must be used for comparisons. This method was found too time consuming and a rapid technique was needed.

It had been noticed when peanut leaves were dipped in water and withdrawn that only the abaxial surface retained moisture and that the rate of withdrawal affected the amount of water retained. It was decided to investigate these observations further.

Dipping methods for determining the wettability of leaves and the retention of aqueous suspensions on leaves have been utilized (1, 3, 14, 16) but the rate of withdrawal was disregarded.

Materials and Methods

A simple apparatus was devised to allow the water to be drained from around the leaflet rather than withdrawing it from the water (Fig. 1). A cylindrical plastic bottle, with the bottom removed, was inverted and held vertically by a retort stand. A short length of glass tubing was inserted through a rubber bung in the neck. A rubber tube with a clip was attached to the glass tube. The rate of lowering of the water in the bottle could be changed by varying the diameter of the outlet in the neck with the use of glass tubing of different bore.

[1]Portion of a thesis submitted by the author to the University of the West Indies in partial fulfilment of the requirements for the Ph. D. degree.

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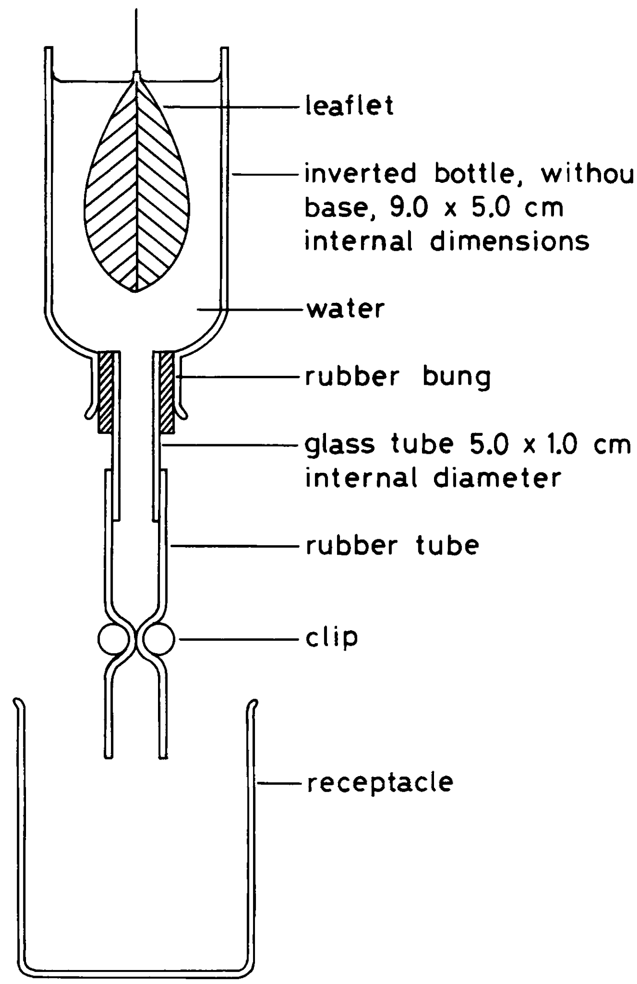

Fig. 1. Diagram of the constant drainage apparatus used to assess the wettability of peanut leaves.

Peanut leaflets of various wettability were investigated with the apparatus to establish a satisfactory drainage rate. After weighing on a torsion balance, the leaflet was lowered vertically into the water. The clip was then released and the water drained from the bottle. The leaflet was reweighed and the adhering water determined by difference. This was expressed as mg water retained per 10 cm^2 abaxial leaf surface.

A discarded microscope was converted into a microprojector. Contact angles were assessed by the method of Fogg. (9); droplets around 3 mm in diameter and a 50 fold magnification of droplet image being used. Contact angles were calculated in degrees to the second decimal place rather than in degrees and minutes.

Two 8 week old plants of each of the cultivars Starr, Tarapoto (PI 259747), NC 4X, Georgia, NC 13, F 393-6, Florigiant and V 61R were used to calibrate water retained with mean contact angle measurements. These cultivars embrace a wide range of peanut growth/maturity types. Plants with fully turgid leaves were brought into the laboratory from the greenhouse. The wettability of the abaxial surface of leaves that had just opened and leaves that were 4, 14 and 35 days old on the main axis of each plant was determined by the two methods of assessment. One of the distal leaflets of each leaf was used for determining water retention. The other distal leaflet was used for contact angle measurements, 10 of these being made, five on each strip of lamina cut from either side of the midrib. The leaflets were detached when needed and their wettability immediately assessed since the wettability of leaves varies with their water content due to changes in corrugation of the leaf surface (2, 8, 9).

Results

It was found that the faster the rate of drainage, the more water the abaxial leaflet surface tended to retain. Likewise, the longer the period of leaflet immersion before the initiation of drainage, the greater the amount of water retained. To obtain replicable results for water adhesion it was necessary to drain the water at a constant rate after a standard time interval of leaflet immersion. Drainage of the water approximately 1 second after leaflet immersion at a rate of 2.5 cm/second gave good discrimination over a wide range in wettabilities of various peanut leaflets. It was not necessary to take repeated readings with the same leaflet since readings subsequent to the first were either identical or showed a slight creeping rise in value after each successive immersion. The adaxial leaflet surface never retained any water regardless of the rate of drainage.

Standard deviations of mean contact angles were large, but independent of the mean and comparable in magnitude with the observations of other workers. No trend was found in the variation of contact angle of the water droplets either between leaflet base and tip or between left and right half leaflets. The slight heating effect of the lamp in the microprojection apparatus did not affect the leaflet strips in the time required to make droplet image tracings. Moreover, this heating effect had virtually no affect on the water droplets (6).

For each of the cultivars the relationship between the results for the two methods of wettability assessment appeared to be linear (Table 1). An analysis of covariance was performed to determine if the regressions of contact angle on water retained were the same. No significant differences among these were found with respect to residual variances, slopes or elevations and the results for the cultivars were combined to calibrate mg water retained with mean contact angle measurements.

The regression of mean contact angle (Y) on water retained (X) (Fig. 2) was approximately linear and the regression line:

$$Y = 122{,}401 - 2.54X$$

was fitted to the data. The correlation between the two variables was very high, $r = 0.997$ ($P = 0.001$).

The portion of the regression between the 10 and 30 mg points on the X axis was virtually linear but the extensions

Table 1. Regression data of mean contact angle of abaxial leaf surface (Y) on mg water retained/10 cm² abaxial leaf surface (X) for two 8 week old plants of eight peanut cultivars.

Leaf age[a]	Sample variables							
	X[b]	Y[c]	X	Y	X	Y	X	Y
	Starr		PI 259747		NC 4X		Georgia	
0	39.58	30.47 ± 3.28	36.81	38.83 ± 3.88	38.14	32.85 ± 4.76	36.56	34.45 ± 1.30
	39.18	33.77 ± 4.07	35.56	37.38 ± 4.76	37.62	35.05 ± 3.16	34.16	39.37 ± 4.79
4	31.09	48.15 ± 2.09	27.21	58.93 ± 4.63	28.90	51.48 ± 3.72	26.35	58.63 ± 3.42
	29.28	54.22 ± 3.51	22.23	70.17 ± 4.20	27.34	55.37 ± 1.95	21.63	74.80 ± 5.21
14	23.85	67.70 ± 2.56	18.07	77.88 ± 3.61	22.18	66.60 ± 3.99	17.88	80.17 ± 3.72
	18.12	82.82 ± 5.50	15.61	87.35 ± 4.81	18.94	76.62 ± 3.72	14.51	86.70 ± 4.21
35	10.76	100.60 ± 4.04	9.09	102.02 ± 4.78	7.42	103.78 ± 4.33	5.38	108.87 ± 4.17
	10.31	96.70 ± 5.74	8.27	105.58 ± 4.99	5.75	110.83 ± 4.51	3.16	115.22 ± 2.67
	NC 13		F 393-6		Florigiant		V 61R	
0	34.83	40.47 ± 3.92	31.84	44.47 ± 4.26	33.92	45.10 ± 4.21	29.58	49.26 ± 3.70
	32.26	47.47 ± 2.86	31.41	50.20 ± 4.77	32.27	45.95 ± 1.70	25.08	59.32 ± 4.45
4	24.31	67.40 ± 4.50	24.82	63.70 ± 5.33	24.10	64.42 ± 3.19	20.30	75.62 ± 4.01
	20.36	78.15 ± 4.03	21.25	69.42 ± 3.76	19.20	77.92 ± 4.98	19.11	73.18 ± 4.95
14	13.56	92.72 ± 4.38	15.74	84.05 ± 4.07	13.10	89.78 ± 4.99	11.32	98.27 ± 4.47
	12.50	97.38 ± 5.30	12.54	93.23 ± 1.82	8.69	104.32 ± 5.56	7.19	107.33 ± 4.96
35	2.10	114.57 ± 3.20	0.41	120.62 ± 3.29	5.60	112.63 ± 2.85	2.28	118.94 ± 3.87
	0.75	115.78 ± 4.81	0.06	118.70 ± 4.01	4.13	113.15 ± 5.10	1.93	116.65 ± 5.32

[a] Leaves aged in days from leaflet opening.

[b] Mg water retained/10 cm^2 after drainage of water at 2.5 cm/second from around the leaflet.

[c] Mean and standard deviation of 10 contact angle determinations.

on either side were not. A logistic curve was fitted to the data by the method of Cowden (5):

$$Y = \frac{155.722}{1 + 3.9095\, e^{-0.0645\,(40 - x)}}$$

Analysis of variance showed that the curvilinearity in the regression was significant (P = 0.01).

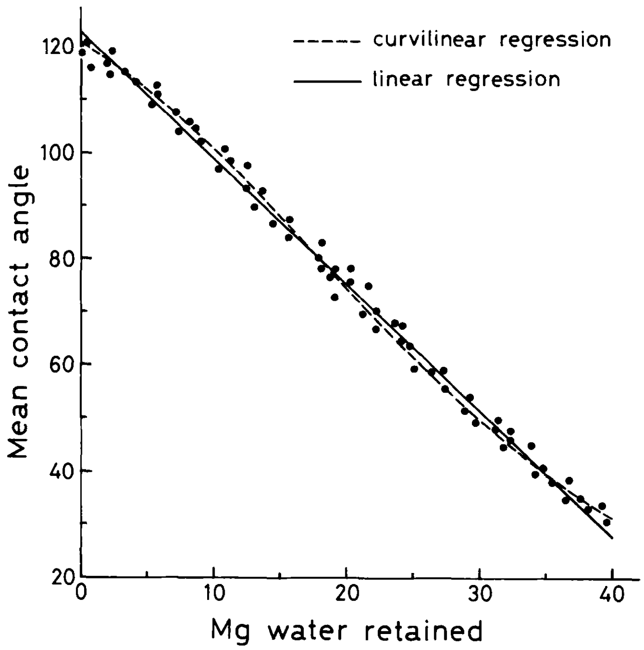

Fig. 2. The regression of mean contact angle of abaxial leaf surface on mg water retained per 10 cm^2 abaxial leaf surface for peanut leaves.

Discussion

That the drainage rate had to be constant was due to the enhanced ability at slower rates of the receding meniscus to pull adhering water from the leaflet surface. The greater retention of water after longer periods of leaflet immersion prior to drainage may have been partly due to water entering the leaflet through stomata. Water infiltrating the leaflet may also account for the gradual rise in retention sometimes found after successive leaflet immersions.

Although the constant drainage technique results were dependent on the receding contact angle while the standard method of assessing wettability depends on the advancing contact angle, this was of little account as a high degree of correlation exists between advancing and receding contact angles (7). The correlation between mean contact angle measurements and mg water retained on the leaf surface was very high. However, the regression of mean contact angle on water retained was not strictly linear although it could be considered so for practical purposes; the data were better fitted by a logistic decay curve. The departure from linearity below the 10 mg point on the X axis was partly due to some of the small droplets being dragged off the leaf surface by the receding meniscus thereby decreasing the water retentivity below an expected linear value. Above the 30 mg point, some of the adhering droplets tended to coalesce because of their close proximity to each other on the leaf surface which increased the water retentivity above an expected linear value. At a certain point a continuous film of water was retained by the leaf surface and the limit to the amount of water the glaucous surface could retain had been reached. When a film of water was continuous, retention was sometimes less than when the water remained in close discrete droplets. With agricultural sprays, the retention after run-off is almost always lower than the retention at the point of run-off, but this decrease is dependent on the roughness of the leaf surface (10). Another explanation for these departures from linearity resides in the properties of water droplets themselves. The retention of spray droplets on solid surfaces has been shown by Moillet and Collie (12) to be higher when the values of advancing contact angles are intermediate than when the values are very high or very low. Furmidge (10) showed the relationship to be more complex than envisaged by Moillet and Collie. He stated that retention is governed mainly by the values of advancing and receding contact angles, the degree of contact angle hysteresis, the surface tension of the liquid and the size and impacting velocity of the droplets. On leaf surfaces retention is further complicated by the angle of the leaf and its surface properties (10).

Mean advancing contact angles below about 28^0 (9) or above 173^0 (11) do not seem to be obtainable with water droplets on leaf surfaces. The lowest mean contact angles obtained in this investigation were around 30^0, although some individual measurements were as low as 20^0, and the highest mean contact angles obtained on the adaxial surfaces were around 157^0 even though some individual measurements exceeded 170^0 :the theoretical upper limit for contact angle measurements in 180^0). The figure 155.722 in the logistic equation indicated that the mean contact angle would not exceed this value on the surface of peanut leaves.

The method, with appropriate adjustments to the rate of drainage, can be used to assess the leaf wettability of certain other species. For leaves with both surfaces similarly wettable (the limit of wettability is around 120^0) or with one surface wettable and the other unwettable, the method is suitable for use in the form described (if the unwettable surface is of interest, contact angles must be used to assess its water repellency). For leaves with differentially wettable surfaces, when the wettability of each surface needs to be known independently, the leaf is divided down the midrib into two halves and the surface not under investigation covered with a water repellent substance. For unwettable leaves with both surfaces similarly water repellent, an appropriate concentration of surfactant in the water, or the use of some other liquid, sometimes gives good discrimination over the range in water repellency encountered. However, for unwettable leaves with differentially water repellent surfaces the method is not applicable if the water repellency of each surface needs to be known independently. To assess the wettability of different areas of a leaf surface, visual inspection of the pattern of water adhesion to the surface will often suffice. Alternatively, water-dye may be used and the leaf surface pressed onto absorbent paper to record the regions of greatest wettability. When the wettability of the different areas needs to be quantified, with some species it is possible to cut the leaf into portions and determine the wettability of each piece separately.

This constant drainage technique should prove useful when extensive leaf wettability estimates must be made during a short time period. The technique may be used in the greenhouse and field. With some species it does not necessitate destruction of the leaf, the water retained can be determined from the loss in weight of the apparatus including non-adhered water. This procedure enabled the diurnal fluctuation in peanut leaf wettability and its change with leaf age to be investigated. A direct relationship between the water repellency of peanut leaves and their susceptibility to rust infection was established (4). This relationship and the constant drainage technique can facilitate the rapid detection of cultivars, and lines within cultivars, with potential resistance to rust.

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