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PLANT WATER STATUS OF APPLE TREES AND ITS MEASUREMENT IN THE FIELD. 5. THE DYE TECHNIQUE FOR THE MEASUREMENT OF FRUIT WATER POTENTIAL

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SUMMARY

Of the techniques available for the measurement of water potentials in plant storage organs, most are inconvenient and unsatisfactory for field use. The dye method, a densiometric technique, has been developed for the measurement of apple fruit water potentials in the field. A description of the technique is given. Provided precautions relating to fruit exposure, equilibration time and fruit insertion height are observed, the technique appears to be satisfactory for field use.

The causal effects of variable fruit insertion heights on fruit water potentials require further investigation.

I. INTRODUCTION

Fruit water potentials which are important in fruit-plant water relationships may be measured by a number of methods, similar to those used for other plant storage organs. The gravimetric and volumetric methods are employed but these are unsatisfactory and generally inconvenient because of the surface drying problems encountered and the time-consuming procedures. Of the vapour exchange methods, only that of Slatyer (1958) was available and this, because of the long equilibration time, incurred problems of respiration and tissue breakdown. Of the two densiometric techniques available, the dye method, after Shardakov (1953), was chosen in preference to the refractometric technique (Ashby and Wolf 1947), because of the time savings that could be effected, thereby making the method suitable for field studies.

In this paper a description of the dye method developed for use with apple fruit tissue is given, and the effect of immersion time on the water potential of apple fruits is examined. Since no evidence could be found in the literature on variations in water potential with fruit insertion height on a tree, it was considered desirable to examine this possible effect in the present studies. All work was carried out using three apple varieties—Delicious, Jonathan and Granny Smith.

II. MATERIALS AND METHODS

The dye method.—Two exposed fruits, 5 ft above ground level, were picked from each replicate, placed in plastic bags and brought to the laboratory. With coloured varieties, fruits of uniform colour were selected. Each fruit was sliced perpendicular to the core with a "Dialomatic Food Cutter" to give slices 5 mm thick. Six slices from each fruit were cut with a cork borer to produce discs 19 mm in diameter.

A series of six sucrose solutions of different concentrations and dyed with methylene blue provided the range of osmotic pressures required, in 2 atm steps. Solutions were contained in glass phials 2·5 cm in diameter by 10 cm in length. Two discs of apple tissue, one from each fruit, were placed into each phial, which contained sufficient dyed sucrose solution to cover the discs. Phials were sealed with cork stoppers and left to equilibrate. A parallel series of test undyed solutions was set up. After immersion, discs were removed from the dyed solutions, discarded, and the solutions tested. After mixing, a portion of the dyed solution was extracted with a Pasteur pipette. The pipette was then inserted into the test solution at its midpoint of depth, a drop of dyed solution ejected, and the behaviour of the drop observed. Where the drop fell at one concentration and rose at the next, the water potential was assumed to lie midway between those two concentrations.

When testing of solutions was to be deferred, phials were restoppered, after discs were removed, sealed over the cork with hot paraffin wax and stored at low temperature.

Equilibration time and fruit water potential.—For the three varieties, changes in the water potential of fruit with equilibration time were recorded for fruits taken from plants at high and low stress. Three field replicates (single-tree plots) and six equilibration times (0·5, 1·0, 4·0, 6·0, 8·0 and 24·0 hr) were utilized for each variety at each stress.

Insertion height and fruit water potential.—Five field replicates (single-tree plots) of each of three varieties were selected for sampling. Two fruits were sampled from each of three heights above ground (3, 5 and 8 ft) from each of the five replicates. The fruits were brought to the laboratory and water potentials were determined using the dye technique. Samples were taken on two occasions to depict behaviour at high and low stress levels.

III. RESULTS

Equilibration time and fruit water potential.—Figures 1-3 show the results for the three apple varieties at the two stress conditions. In general, the effect of equilibration time on water potentials of fruits was small. In only one case, with Jonathan at low stress, was water potential significantly influenced by equilibration time.

Insertion height and fruit water potential.—Table 1 presents data for the three varieties at the two stress conditions. With Delicious there were no differences. For Jonathan, differences were found at high stress, while for Granny Smith insertion height influenced potentials at both the high and the low stress conditions.

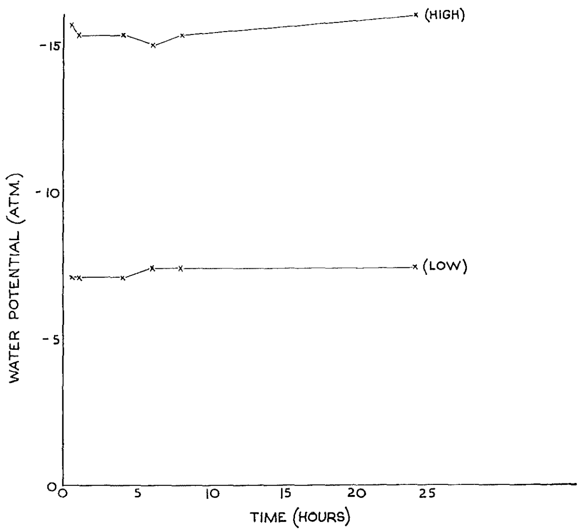

Fig. 1.—Relationship between estimated fruit water potential and equilibration for Delicious at high and low stress.

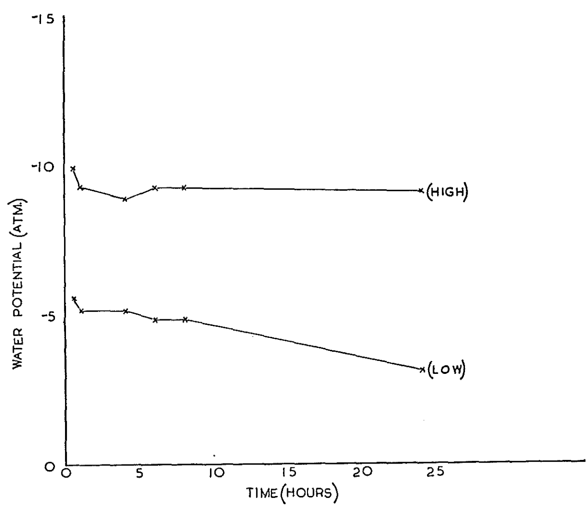

Fig. 2.—Relationship between estimated fruit water potential and equilibration time for Jonathan at high and low stress.

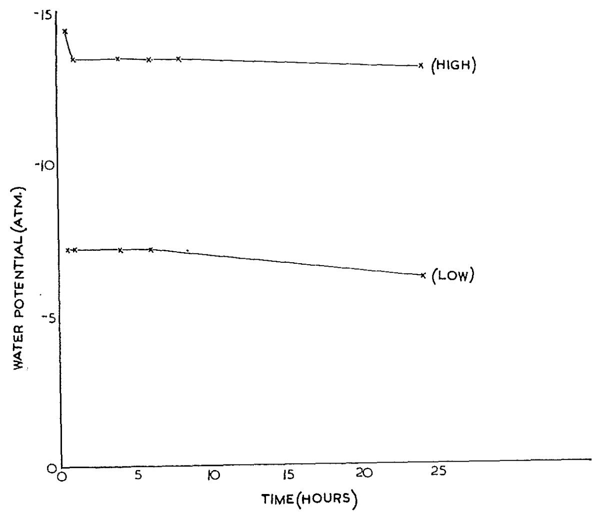

Fig. 3.—Relationship between estimated fruit water potential and equilibration time for Granny Smith at high and low stress.

TABLE 1

VARIATIONS IN FRUIT WATER POTENTIAL (ATM) WITH INSERTION HEIGHT FOR THREE APPLE VARIETIES AT TWO STRESSES

Variety	Stress	Fruit Insertion Height			L.S.D.	
		3 ft	5 ft	8 ft	5%	1%
Delicious ..	Low	−5·76	−5·57	−5·58	n.s.	n.s.
	High	−11·50	−11·30	−10·92	n.s.	n.s.
Jonathan ..	Low	−3·13	−3·32	−3·10	n.s.	n.s.
	High	−10·20	−11·68	−11·50	1·20	n.s.
Granny Smith ..	Low	−9·66	−10·74	−10·20	1·05	n.s.
	High	−12·70	−14·24	−12·70	1·38	n.s.

IV. DISCUSSION

Water potential of fruit tissue in the early stages of equilibration was variable. This early "time" effect trend, which was also noted with leaf tissue (Chapman 1970) was attributed to the absorption of water onto the surface of the tissue and to exudation or uptake of solutes from the cut discs. A comparison should be made of the effects of disc size (varying cut surface to bulk ratios) to establish whether absorption or exudation and uptake effects contributed most to these errors.

It seems that, in all cases, except for Delicious and Granny Smith at low stress, these early "time" effects were present, but they did not significantly influence results obtained.

With Jonathan at low stress, water potential at 24 hr was considerably higher than at 4 hr. This appeared to be due to tissue decay during this longer period, which was noticeable for all varieties but seemed to be worse for Jonathan.

Therefore, for the three varieties a short equilibration time, somewhat less than 6 hr but longer than 30 min, is satisfactory. Four hours was selected for further work because up to this stage tissue decay was minimal and initial "time" effects were absent.

With regard to the influence of fruit insertion height on water potential, it seems that height does affect potentials, but in a way which appears to be dependent upon variety. Differential shading effects, transpiration rates, tree form, crop loading, assimilate supplies, and competition for water between fruits and other plant parts could all contribute to the observed results.

A uniform sampling height is desirable. It appears that the effects of insertion height should be examined for each variety. The contributing factors, indicated above, which can influence potentials at the various insertion heights need to be examined in detail to elucidate their basic influence mechanisms.

This modification of the dye technique for use with apple fruits in the field appears to be quite satisfactory provided the precautions relating to exposure, equilibration time and insertion height are examined for each variety in each situation encountered.

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