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A NOTE ON TEMPERATURE AND VAPOUR PRESSURE DEFICIT UNDER DROUGHT CONDITIONS IN SOME MICROHABITATS OF THE BURREN LIMESTONE, CO. CLARE.

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The large area of karst-like limestone which forms the Burren region of Co. Clare is noted for a flora of remarkable diversity. Apart from the unusual number of phytogeographical elements represented in the district, the vegetation contains a striking admixture of ecological types; calcicole and calcifuge species commingle freely, and xerophytes, mesophytes, hylophytes and hygrophytes are frequently to be found juxtaposed. This diversity must, of course, be attributable largely to the range of microhabitats and microclimates which this type of jointed and fissured limestone landscape offers in the extreme oceanic climate of western Ireland. There are, however, few recorded microclimatic data for the Burren as yet, either in the form of continuous records or isolated observations. Even the latter may be significant in understanding the ecology of the area, especially should they refer to extreme conditions, particularly of heat and drought, when the tolerance limits of various members of the flora are being approached. The present note places on record some observations made during a period of severe drought, towards the end of May, 1959, after a rainless period of more than four weeks.

May is normally the driest month of the year throughout much of the western seaboard of Ireland, and the rainfall during May, 1959, approached the lowest recorded values for the month in many parts of the country. Air temperatures and daily durations of sunshine were also exceptional, particularly during the period, 25th–27th May, when the present observations were made. Thus on 25th May the observatory at Rathfarnham Castle, Co. Dublin, recorded 14·8 hours of sunshine, a record for one day in May at this station. On this same day, maximum Stevenson-screen temperature at Shannon Airport, Co. Clare, was 75° F. (23·9° C.), a quite exceptionally high value for this station.

During the days when observations were made, the skies over the Burren were cloudless practically from dawn to dusk, although a dense low haze accumulated over Galway bay in the late afternoons. Barometric pressure remained in the range 1028–1030 millibars, with light winds from north or north-east.

Relative humidities were measured using dial-indicating hygrometers manufactured by A. and A. Equipment Ltd. of Leeds. These are actuated by an impregnated fibre element, and within the range 40–85% RH show an accuracy of within 3% in comparison with values obtained from wet and dry bulb thermometers. Their principal drawbacks are the comparatively long times required to reach equilibrium, due to the relatively high moisture capacity of the element, and a liability to lag-effect inconsistencies depending upon whether a new value is approached from a lower or higher previous value. The values recorded in the field were those indicated when two successive readings at intervals of five minutes showed less than 1% difference, usually after an equilibration period of twenty or more minutes. Between observations, the instruments were kept in a plastic bag, where they returned to readings of 68–70%. All field readings below this range were therefore reached with the element tautening, and those above with the element relaxing. The errors are thus on the whole such as to compress the indicated range of differences. From time to time the hygrometers were adjusted after equilibration in still air to agree with the relative humidity value calculated from observations of Casella whirling wet and dry bulb thermometers.

The observations were made between 11 a.m. and 3.30 p.m. GMT. As comparison standards for each site, 'air' and 'surface' temperature and relative humidity readings were taken over the nearest area of unshaded limestone pavement, or, in the scrub sites, in clearings. The air values were obtained at shoulder level (*c.* 1·5 m.) with the whirling wet and dry bulb thermometers, and the surface values with a shaded-bulb mercury-in-glass thermometer in direct contact with the limestone, and a shaded dial-indicating hygrometer placed with the sensing element *c.* 8 cm. from the surface. In the various microhabitats, relative humidities were recorded with the hygrometers placed so that the sensing element lay in shade at the level of the foliage. Temperatures were recorded with shaded bulb thermometers placed in corresponding positions. In some cases temperatures in rooting layers and bryophyte carpets were recorded in the vicinity at the same time.

The values for dry bulb temperature and relative humidity have been used to estimate vapour pressure deficit using the nomograms of Gordon (1940). All conversions have been based upon a barometric pressure of 1030 millibars, without correction for altitude. Observations for a series of sites of varying character are recorded in Table I.

TABLE I

Dry-bulb temperatures and vapour pressure deficits in some microhabitats of the Burren limestone, Co. Clare. Recorded after drought, 25th–27th May, 1959.

PAVEMENT LIMESTONE, INLAND SITES.

Localities and habitats.	Dry-bulb temperature °C.	Vapour pressure deficit mm. Hg.
I. Carron, *c.* 620 ft. O.D., 8 miles inland		
A, Air at *c.* 1·5 m.	28·0	16·5
B, Rock surface	33·0	21·5
C, Depth of 115 cm. in a fissure with *Phyllitis scolopendrium* and *Rubus caesius*	16·0	3·7
D, Depth of 30 cm. in solution hollow with 2–3 cm. powdery black peat	24·0	11·0
E, Small tussock of *Sesleria caerulea*	32·0	—
F, Rooting layers of *Saxifraga tridactylites*	26·0	—
G, Mat of *Ctenidium molluscum*	31·0	—
II. Cullaun, *c.* 750 ft. O.D., 5 miles inland		
A, Air at *c.* 1·5 m.	23·0	9·5
B, Rock surface	30·0	19·0
C, Depth of 185 cm. in a deep fissure with luxuriant *Asplenium trichomanes, Sanicula europaea, Circaea lutetiana* and dwarf *Fraxinus* and *Ilex*	14·5	1·8
D, Carpet of *Sesleria caerulea*	21·5	—
E, Rooting layers of *Dryas octopetala*	24·5	—
F, Shallow peat with *Calluna vulgaris*	21·0	—

PAVEMENT LIMESTONE, COASTAL SITES.

Localities and habitats.	Dry-bulb Temperature °C.	Vapour pressure deficit mm. Hg.
I. Black Head, *c.* 35 ft. above water level at the time of observation		
A, Air at *c.* 1·5 m.	22·0	10·5
B, Rock surface	31·0	19·0
C, Joint at 45 cm.; partly sand-filled and without vegetation	20·5	3·9
D, Rooting layer of *Gentiana verna*	23·0	—
E, Rooting layer of *Saxifraga hypnoides*	26·5	—
II. Murrough, *c.* 12 ft. above water level at the time of observation		
A, Air at *c.* 1·5 m.	23·0	10·1
B, Rock surface	33·0	17·4
C, Fissure at 60 cm. with *Armeria maritima* and *Plantago maritima*	16·0	1·6

SCRUB WOODLAND.

Localities and habitats.	Dry-bulb temperature °C.	Vapour pressure deficit mm. Hg.
I. Carron, *c.* 620 ft. O.D. Open *Corylus* scrub		
A, Air at *c.* 1·5 m. over open limestone	28·0	16·5
B, Rock surface	33·0	21·5
C, Sun-flecked carpet of *Hylocomium brevirostre* under *Prunus spinosa*	23·0	9·1
D, Shade under *Crataegus monogyna*, with *Arum maculatum*, *Primula vulgaris* and *Hylocomium loreum*	22·0	6·9
II, Glensleade Castle, *c.* 450 ft. O.D. Fissured limestone, with dense *Corylus* scrub, canopy up to 4 m.		
A, Air at *c.* 1·5 m., 3 m. from shade	22·0	10·4
B, Rock surface, 3 m. from shade	28·0	15·3
C, Depth of 135 cm. in fissure with *Phyllitis scolopendrium* and *Breutelia chrysocoma*	13·0	1·1
D, Edge of *Corylus* thicket, on a carpet of *Thuidium tamariscinum* and *Hylocomium splendens*, with *Viola riviniana*, *Geranium robertianum*	18·0	3·5
E, Shaded rock surface in small clearing with *Camptothecium lutescens*	21·0	7·1
F, Hazel crotch at upper limit of epiphytic *Ulota crispa*	23·5	6·0
G, Upper limit of *Corylus* canopy, 3·5 m.	29·0	—

CLIFFS AND ESCARPMENTS.

Localities and habitats.	Dry-bulb temperature °C.	Vapour pressure deficit mm. Hg.
I. Caher Bridge, *c.* 420 ft. O.D.		
A, Air at *c.* 1·5 m. over level limestone	26·0	11·5
B, Surface of open rock	34·0	20·2
C, Moderate north-facing declivity with *Ceterach officinarum*, *Cystopteris fragilis*, *Asplenium ruta-muraria* and *Sesleria caerulea*	25·0	11·0
D, A gulley beneath an overhang with *Cratoneuron commutatum*, north-west aspect	21·0	6·4
II, Black Head, 85 ft. O.D.		
A, Air at *c.* 1·5 m.	22·0	10·1
B, Surface of open rock	31·0	19·1
C, Shallow depression on a north-easterly declivity with dwarfed *Adiantum capillus-veneris*	16·5	4·8
D, Distance of 1·6 m. within a small cave opening northwards, with luxurious *Adiantum capillus-veneris* and a carpet of *Conocephalum conicum*	12·5	0·8

Since the work of Maximov and Livingston, botanists have accepted that the vapour pressure deficit (occasionally termed saturation deficit) of the atmosphere must be a primary factor governing transpiration, and this principle is re-stated in most modern text-books of plant physiology (e.g., Bonner and Galston, 1952; Thomas, Ranson and Richardson, 1956). This view has, however, been dismissed as untenable by Leighly (1937), who points out that in still air the rate of evaporation is proportional to the difference between the saturation vapour pressure at the evaporating surface and the prevailing vapour pressure of the atmosphere, and not to the vapour pressure deficit of the atmosphere. Only if the evaporating surface is at the same temperature as the air will there be proportionality between evaporation and vapour pressure deficit, and Thornthwaite (1940) has been at some pains to cite apparent paradoxes arising from the orthodox view when the temperatures of the evaporating surfaces are not taken into account.

These criticisms are not entirely disastrous for ecologists who have accepted vapour pressure deficit as an index of the evaporating power of the atmosphere, for there is no readily derived index available which is any better, at least when it is transpiration from leaf surfaces which is under consideration. Whereas the temperatures of soil and water surfaces may depart considerably from atmospheric temperature and may sometimes be low enough for condensation to take place from air with an appreciable vapour pressure deficit, leaves are rarely cooler than the surrounding atmosphere, and are usually some degrees warmer in sunshine when stomatal transpiration is likely to be at its maximum. Thus any error involved in accepting vapour pressure deficit as an index of the contribution of atmospheric conditions to water loss is likely to be in the direction of underestimation, for the difference between the saturation vapour pressure at the leaf surface and the vapour pressure of the air is always likely to be greater than the vapour pressure deficit of the atmosphere.

Although fragmentary observations such as those recorded in Table I are no substitute for continuous records of diurnal and annual variations in the microclimates of the Burren, they are of interest in that they were made under extreme conditions of drought, and therefore represent the most severe conditions of moisture deficiency likely to be experienced by the flora of this hyperoceanic region during the peak of a growing season. Bearing in mind that the vapour pressure deficit probably underestimates the effects of atmospheric dryness upon transpiration from unshaded vegetation and that wind would increase water loss in the exposed locations, it is clear that very great differences can develop in moisture stress and temperature between neighbouring habitats. It is obvious, for example, that even relatively shallow fissures in the limestone rock supply a habitat which must be consistently humid and cool through the year, whilst the exposed rock surface nearby may reach at times lethal heat and extreme dryness. The equable conditions of the fissures are no doubt attributable to the vast water reserves in the rock; evidently even a month of drought is sufficient to dry out only the surface and to make no appreciable inroads on the water content of the huge limestone sponge which forms the Burren.

The striking effect of hazel scrub on microclimate is obvious from the recorded figures. The bushes are often rooted deeply in fissures, and clearly are capable of tapping deep water resources. Their influence upon climate beneath the canopy is, of course, evident from the mesophytic flora sustained there even in the shallowest of soils over the limestone surface, but it is interesting to note that low vapour pressure deficits may be developed there at higher air temperatures than in fissures in the open limestone, a fact which must considerably influence relative growth rates of mesophytic species in the two habitats. This carries a lesson of some practical importance, namely that attempts to clear the hazel scrub woodland will not improve, but indeed lower, the productivity of the vegetation for grazing purposes. The bushes are important in the mobilisation of deep water reserves, and their indiscriminate removal can do nothing but impoverish surface vegetation. Probably the maximum yield is already being obtained in those very large tracts where cattle commonly gaze freely through the scrub, beating their own regular passages, and so keeping the canopy open enough to allow adequate light through to the ground flora whilst not destroying its effect on microclimate. These remarks refer, of course, to hazel scrub formed over the limestone tracts, and not to that on drift soils.

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