SOME AIR TEMPERATURE READINGS AT SEVERAL STATIONS ON SLOPING GROUND.

BY ROBERT S. VINSON AND EDWARD J. RUSSELL, D.Sc. (Lond.).

(*South-Eastern Agricultural College, Wye.*)

It is well known that the mean temperature falls as the elevation increases, and partly on this account certain crops cannot profitably be produced on high land. But it is also recognised that low lying land is subject to lower minimum temperatures, and is therefore more liable to frost¹, than land higher up, and low situations are consequently avoided by fruit and early potato growers. Few actual temperature readings have, however, been published.

We have recently been making an experimental study of the phenomena of spring frosts, and have taken a series of temperature readings at several stations on a slope about a mile and a half long with a total difference in altitude of 580 feet. The slope is on the North Downs, which here run in a S.E. and N.W. direction; away to the S., S.E. and S.W. stretches a large plain. There are eight stations in all, one on the top, two on the banks of the river Stour at the bottom, and the other five come in between; the series form a somewhat irregular line running E. and W. in the positions shown in the following table.

TABLE I.
Position and description of stations.

No. of station	Height above sea level in feet	Height above river at station 7	Distance from station 7	Situation
1	675·21	581·69	7322·5	At the top of the Downs
2	285·34	191·82	5284	Poor pasture field
3	232·34	138·82	4126	Young corn crop
4	174·37	80·85	2691	Uncropped ground; somewhat sheltered from the north by a plantation
5	119·34	25·82	558	Pasture land
6	97·00	3·47	196	"
7	94·52	1·00		River bank, confluence of river and ditch
8	97·00	3·47		River bank, straight part

¹ Theophrastus mentions this fact (lib. v. c. xx.) and also Pliny (lib. xviii. cc. 69, 70); other old references are given in Boussingault, *Chimie Agricole*, II. 378, and in Warington, *Physical Properties of Soil*, pp. 184 *et seq.*

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Stations No. 7 and 8 are intended to find what effect is produced by running water; No. 7 is much more surrounded than No. 8. The river is here 40 ft. wide and very slow. Mr R. S. Biscoe kindly determined the altitudes and distances.

At each station readings were taken at 6 inches and at 2 metres above the ground: they were started on April 14th and had to be discontinued on May 31st. There is a little uncertainty about some of the readings at 2 m., because strong winds shook the thermometers, and at times readings could not be taken but had to be calculated from the results obtained at the stations above and below. The average values used here are probably only slightly affected. Maximum and minimum temperatures were read at stations 1 and 6, but at the other stations minimum readings only were taken; the thermometers were fixed on posts in the open and had no protection whatsoever. All the thermometers used were checked against a standard thermometer with a Kew certificate.

Minimum Readings.

The means of all readings are given in Table II.

TABLE II.

Average minimum temperatures, degrees C., April 14th to May 31st, 1907.

							River bank	
No. of station	1	2	3	4 ¹	5	6	7	8
Minimum temperature at 6" above ground	3·4	3·2	3·3		2·6	2·2	3·3	3·0
" " 2 m. "	3·8	3·4	3·6		3·2	3·2	3·1	3·1

Two distinct phenomena are here involved, the effect of elevation and the effect of water on temperature. Beginning with the former of these it will be noticed that the ground temperature reaches a maximum at the top station, and falls with decreasing altitude to a minimum at No. 6. The temperatures 2 metres up are somewhat higher than the ground temperatures, especially at Nos. 5 and 6. There is the same fall with decreasing altitude, but the gradient is much less marked, and at the four lower stations substantially the same readings are obtained.

¹ Readings spoiled by wind on several nights, and therefore omitted from this Table.

The effect of water will be discussed in detail later on, it is very strikingly shown at No. 7, where the ground temperature is a degree higher than at No. 6, although the two stations are less than 200 ft. apart and lie in the same field. At 2 metres the effect no longer shows.

These phenomena occur to a marked extent on still nights.

TABLE III.

Average minimum temperatures, 11 still nights during experimental period.

No. of station	1	2	3	4	5	6	River bank	
							7	8
Minimum temperature 6" above ground ...	2.8	2.0	2.2	1.9	.6	0	1.5	.9
" " 2 m. " ...	3.3	2.5	2.7	2.6	1.3	1.2	1.3	1.4

The difference in ground temperature at stations 1 and 6 has now increased to nearly 3° , and the warming effect of the river is well seen. At 2 metres the temperature is a shade lower at No. 6 than elsewhere, but there is very little difference between stations 5, 6, 7, and 8. These gradients are plotted in Fig. 1; it will be observed that they run parallel as far as station 5.

FIG. 1. Temperature gradients on still nights.

The usual explanation of the coldness of the lower ground on still nights is that as the temperature falls the layer of air near the ground is cooled, increases in density and tends to roll down the slope and collect on the plains or in the valleys. Here it displaces the warmer

air, which, being lighter, rises and flows over the upper slopes from whence the cold air has come, keeping these slopes at a higher temperature than the lower ones. This explanation is quite in accordance with all our results.

It is not only on still nights, however, that these effects are produced. We also observed them when there was a south or south-east wind, whilst the reverse effects were seen when the wind came from the north or north-east. We are not prepared to explain this result, but it is probably significant that the south and south-easterly winds blow over the plain and travel up the slope in the same direction as the drift of warm air. Apparently the downward flow of cold air near the ground is not prevented. There might, of course, be a greater cooling of the ground in the valley than on the hill, but this is very unlikely; the moist valley soil probably cools less quickly at night than the dry hill soil. Another important point is that the higher stations are naturally more exposed to the wind, and show the warming of the south wind, and the cooling of the north wind more than the less exposed stations lower down.

TABLE IV.

Average minimum temperatures, nights when wind is blowing.

No. of station	S. or S.E. wind blowing up the slope. Average of 7 nights		N. or N.E. wind blowing down the slope. Average of 6 nights	
	6" above ground	2 m. above ground	6" above ground	2 m. above ground
1	6·0	6·2	0·9	0·9
2	5·8	5·5	1·2	1·3
3	5·6	5·8	1·4	1·6
4	5·4	5·8	1·9	2·1
5	4·3	5·6	1·3	1·3
6	3·5	5·0	1·6	1·8
7 (River bank)	5·4	5·1	2·5	2·1
8 (River bank)	4·4	5·0	2·0	1·6

Closely connected with the difference in temperature at stations 1 and 6 is the difference in reading between the thermometers placed at 6" and at 2 m. On still nights, and with a S. or S.E. wind, the temperature at 6" is from $\cdot 2^{\circ}$ to $1\cdot 5^{\circ}$ lower than at 2 m., while with a N. or N.E. wind the difference is much less, and vanishes at stations 1, 2, and 5.

Effect of the river.

It has already been pointed out that stations 7 and 8 on the river are always warmer than station 6, 196 feet from the edge, but in the same field. Station 7, at the point where a ditch flows in, is almost surrounded by water, and shows a higher temperature than station 8, which is on a straight part. The warming effect is probably due to the high specific heat of water and the absorptive power of its vapour preventing a great fall in temperature during the night; it is only seen near the ground, and disappears at 2 m. The readings at 6 inches are given in Table V.

TABLE V.

*Average minimum temperatures at and near river bank.
6" above ground.*

	Station 6, 196 ft. away from river	Station 8, on river bank, straight part	Station 7, on river bank, confluence of river and ditch
Minimum, all nights	2.2	3.0	3.3
Excess on river bank		.8	1.1
Minimum, still nights	0	.9	1.4
Excess on river bank		.9	1.4
Minimum, nights with S. or S.E. wind...	3.5	4.4	5.4
Excess on river bank		.9	1.9
Minimum, nights with N. or N.E. wind	1.6	2.0	2.5
Excess on river bank		.4	.9

It should be noticed that the river is only 40 feet wide.

We cannot say how far from the bank the warming effect is perceptible, but practical men have long since recognised that fields and gardens near a river or a large mass of water suffer less from frost than those further away. Instances of this protective action can be found all along the north Kent coast. The Isle of Grain is less liable to frost, and therefore more suited to early potatoes, than the Hundred of Hoo, situated a little further from the water. Fruit close to the coast suffers less from frost than that a little inland. It is noticed in Worcestershire that gardens within 50 yards of the river Avon suffer less than gardens at a greater distance, whilst in California the influence of a river is so well recognised that land along the bank, and particularly at a bend, where the protective effect is intensified, is considered to be more valuable for certain fruits than land elsewhere.

On a slope like the one under consideration three zones can be distinguished, one near the river somewhat protected against frost, a second further away but on the low ground, and liable to frost, a third still further away on the high ground much less liable to frost. These zones are shown diagrammatically in Fig. 2; their relationships are important to the fruit and early potato grower in spring, and to the gardener in autumn.

FIG. 2.

Maximum temperatures and temperature amplitudes.

Maximum readings were taken at stations 1 and 6, and the results show that during the day the temperature in the valley is higher than on the hill and in consequence the temperature amplitude is nearly 4° greater.

TABLE VI.

Average maximum and minimum temperatures, April 14th to May 31st.

	Station 1, top of slope	Station 6, bottom of slope	Excess at 6
Maximum	14·3	16·7	2·4
Minimum	3·4	2·2	1·2
Total variation ...	10·9	14·5	3·6

The fact that low land is colder by night and hotter by day than land higher up is well known and is also exemplified in the different character of plant growth in the two situations.