Climate of the Horowhenua Lowlands

J. D. Coulter
New Zealand Meterological Service

NEW Zealand lies within the middle latitude belt of predominantly westerly winds, where the weather is dominated by a series of moving pressure systems such as the anticyclones and depressions of the weather map. The overall effect of these systems is to produce a changeable climate, with variable surface winds and irregular periods of rain and sunshine.

In most of the lowland areas of New Zealand, none of which are very far from the sea, this climate has been described in climatic classification schemes, such as those of Koppen and of Thornthwaite, as "warm temperate maritime (or humid mesothermal) without a marked dry season". Such classifications are generally based on seasonal averages of precipitation and temperature, these being, generally speaking, the most important climatic elements. Robertson (1959) has presented a classification of New Zealand climates which attempts to take account of additional weather elements whenever considered important. In it the western coastal areas of Wellington province are described as follows:

"West to northwest winds prevail, with relatively frequent gales. Mean annual rainfall 35-50 in. Rainfall reliable and evenly distributed throughout the year. Warm summers, mild winters."

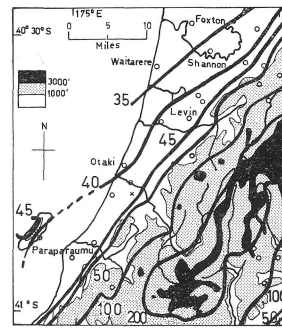

Fig. 1—Mean annual rainfall (ins.). The locations of climatological and rainfall stations are indicated by circles. The cross indicates the forest site near Otaki.

The purpose of this paper is to describe the climate as an environmental factor in the ecology of a forest area near Otaki. The vegetation and soil of the area are described in other articles. Because of the nature of the meteorological data available it has been necessary to treat the climate on a regional basis making such deductions as are possible regarding the local climate of the forest site.

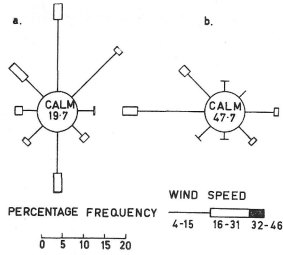

Fig. 2—Mean annual percentage frequency of surface winds (three-hourly observations from Dines anemometers) at (a) Paraparaumu Aerodrome, (b) Shannon.

The climate of the plains and low hills up to about 1000 ft. above sea level from Foxton to Paekakariki that will be described in this paper is relatively homogenous. This is shown by meteorological observations from stations near Levin and Paraparaumu Aerodrome (Fig. 1). These observations are summarised in Tables 1-4 and the following account is mainly based on them. Some additional data from Foxton (sunshine), Shannon (wind), Otaki and a number of other rainfall stations have also been used.

Exposure and Winds

In the free air over New Zealand above about 7000 ft. the wind on most occasions blows from a westerly direction, and the average wind is from nearly due west in all seasons. Near the surface however the directions are more variable; near Cook Strait the air flow tends to be deflected so as to flow approximately northwards or southwards through the Strait, and its speed is locally increased in exposed areas. This effect can be seen in the wind roses for Paraparaumu and Shannon (Fig. 2). At Shannon, in the north of the area, westerlies predominate strongly, there are many calms and light winds, and the average speed is relatively low (5.8 m.p.h.). At Paraparaumu in the south, northerlies predominate, but there are frequent northeasterlies and southerlies as well. Calms are much less frequent and the average speed (9.5 m.p.h. is higher than at Shannon.

The diurnal and annual variation of surface winds is shown in Table 3. The decrease in wind in winter and at night is more marked at inland Shannon that at coastal Paraparaumu. The "surface" wind speeds relate to a standard height of 33 ft. over open country. Near the ground and especially amongst vegetation the speed of the wind is of course much lower.

Between 2000 and 5000 ft. in the free air, the level in which many clouds are found, the wind blows across the Tararua mountains from the northwest to the southwest twice as often as it does in the reverse direction. The region is fully exposed to the northwest and many of the stronger winds from this quarter bring cloudy

weather and showers. These clouds and showers first form over the higher ranges and gradually spread to the foothills and plains. There is some sheltering from the high land with winds from the northern, eastern and southern sectors. This is most pronounced in a general southwesterly air-stream, which frequently gives fine weather in the area when showery conditions prevail in western districts further north. Similarly in a southerly air-stream the Horowhenua plain is often in sunshine while Wellington and the east coast are under cloud; clouds and showers can then usually be seen along the main Tararua range, sometimes spreading to the western flanks and a little way over the plains.

Most low pressure systems (trough lines or depressions) and fronts crossing the area give some rain. However, nearly all the heavy rainfalls are associated with a general northwesterly to westerly air flow over the area. The location of these lowlands north of Cook Strait and west of the Tararua Range accounts for such climatic variation as is observed within the area. Apart from the effects on winds mentioned above there is a general increase in cloudiness and rainfall, and a decrease in sunshine, from the coast towards the hills. Strong winds off the sea are relatively steady and affect most places similarly. Winds which have crossed the mountains tend to be more variable from place to place according to their paths across ridges or through valleys. On sunny days of weak general wind flow, in summer, sea breezes are a marked feature. Their direction is usually northerly to westerly; they are strongest in the immediate vicinity of the beach and often do not penetrate far inland.

Rainfall ane Evaporation

The distribution of average annual rainfall is shown in Fig. 1. The rainfall is about 33 in. on the coast in the north, where the mountains are furthest away, and increases gradually towards Cook Strait and towards the foothills to about 50 in. There is a rapid rise within the ranges to above 200 in. on the tops.

The seasonal trend of rainfall and the variability of monthly rainfall are shown for Otaki, a representative station, in Fig. 3. Otaki has an average rainfall of 39.0 in., ranging from 28.4 in. to 50.2 in. in a period of 70 years. There is only a slight seasonal variation, the difference between the average rainfalls of the wettest months (May, June, July, October) and the driest months (January, February, March) being only about one inch. The variability of monthly rainfall, as indicated by the range between the extremes (or the 10 and 90 percentiles), is also relatively small by comparison with most other areas in New Zealand. That is, the rainfall is relatively reliable.

The maximum intensity of short period rainfalls is also lower in these lowlands than in many other parts of the country. The

amounts of rainfall (in.) in periods of 24 hours, 48 hours and 72 hours calculated from daily records as being likely to be exceeded on the average once in 2 years and 20 years at Otaki and Upper Mangahao Dam are given below.

	24 hours	48 hours	72 hours
Otaki			
Once in 2 years	2.2	2.6	3.0
Once in 20 years	3.5	4.4	4.8
Upper Mangahao Dam			
Once in 2 years	5.8	7.4	8.7
Once in 20 years	10.9	15.4	17.8

The values for the Upper Mangahao Dam (altitude 1200 ft., average annual rainfall 120 in.) show that very intense falls occur within the ranges. Such falls may cause floods in the rivers crossing the plains.

Few measurements of evaporation have been made in the area. The estimated amount of water evaporated from a large open-water surface is approximately 27 in. annually near the hills, and probably over 32 in. near the coast. It ranges from about 4½ to 5in. per month in December and January to about 1 in. in June and July.

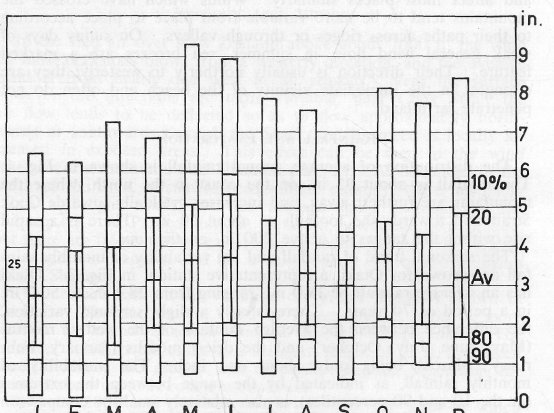

Fig. 3—Rainfall (in.) for each month at Otaki (1893-1960): highest, lowest, average, and the amounts exceeded in 90 per cent, 80 per cent, 20 per cent and 10 per cent of years.

The amount of water lost by evaporation and transpiration from well watered pasture or crops (or, approximately, from any other continuous, uniform vegetation) is determined by current meteorological conditions and has been called "water need" or "potential evapotranispiration". Its value is equal to approximately 4/5 of the corresponding open-water evaporation. Water need varies from day to day, being greatest in conditions of bright sunshine, high temperature, high winds and low relative humidity. However, monthly values do not often depart much from the average for the month in question. Estimated average values of water need for the area are given below, together with the average monthly rainfalls for Otaki for comparison.

	Jan	Feb	March	April	May	June
Water need (in.)	3.8	3.2	2.9	2.0	1.6	1.2
Rainfall (in.)	2.7	2.8	2.8	3.2	3.6	3.8

July	August	September	October	November	December	Year
1.0	1.1	1.8	2.4	2.5	3.5	27
3.7	3.4	3.0	3.7	3.2	3.2	39

Average water need thus exceeds average rainfall in the period December-March by a total of about 2 in. This amount of water would need to be drawn from stored soil moisture or added as irrigation if transpiration were to be fully maintained throughout the "average" year.

The use of averages does not reveal fully the extent to which rainfall may be inadequate for the requirements of vegetation. During wet periods some water is lost through runoff and deep percolation, and there are sometimes long periods when rainfall is below average. This is particularly important in summer when the average is itself low. From Fig. 3 it can be seen that in January in at least three out of four years the rainfall received is likely to be less than water need; and for each of the months from October to April this is likely to be the case in at least one out of five years.

From a study of Otaki monthly rainfall records the amount of additional water that would have been needed from the soil moisture reserve or from irrigation in order to maintain the full rate of potential evapotranspiration averaged 3.8 in. per year, with a maximum in one year (1927-28) of 10 in. The percentage of years in which the estimated rainfall deficiency reached certain values is given below.

Deficiency at least	2 in.	3 in.	4 in.	5 in.	6 in.	7 in.	8 in.
Percentage of years	75	60	45	30	15	10	1

If soil moisture is depleted by more than about 2 in. for any length of time, the exact value depending on the type of soil and the rooting depth of the plants, transpiration is restricted and

growth of pasture declines. At Otaki the calculated soil moisture depletion fails to reach 2 in. in 25 per cent of years; in other years it reaches the figure for a period of up to 5 months. The frequency of such periods is as follows:

Months of depletion	1	2	3	4	5
Percentage of years	20	25	10	15	5

Thus shallow-rooted plants would experience significant water shortage quite frequently, but trees which can draw moisture from considerable depths of soil would probably be affected only occasionally and then only for short periods.

The above analysis is only approximate since it involves assumptions regarding water need and available soil moisture. Also by using monthly rainfall totals it fails to take full account of short-duration dry spells which can influence shallow-rooted plants and seedlings. However, it can be taken as giving an approximate indication of the incidence and severity of dry spells in the area. Dry spells will tend to be somewhat less severe in the higher rainfall areas, but the difference is probably not great over the area with mean annual rainfall below 50 in.

Temperature

The seasonal averages and extremes of air temperature (measured in a standard Stevenson screen at a height of about 4 ft. above the ground) are included in Tables 1 and 2 for two stations in the area, Levin and Paraparaumu Aerodrome. Those for Levin are illustrated in Fig. 4, which also gives averages of grass minimum temperature and 9 a.m. soil temperature at a depth of 1 ft.

Extremes of temperature are neither very high nor very low by New Zealand standards. The maximum recorded is only about 85 deg. F (cf. about 100 deg. F in Canterbury), the average daily range is under 15 deg. F (cf. nearly 20 deg. F at Rotorua), and the annual range (difference between the mean temperatures of the warmest and coldest months) is about 17 deg. F (cf. up to 23 deg. F in Central Otago).

The averages for the number of days in which temperature rises above (a) 75 deg. F and (b) 80 deg. F are given in Tables 1 and 2. There are few days with temperature above 80 deg. F, and an average of only 12 to 14 days per year with temperature above 75 deg. F. Much fewer than in any other area of the North Island except near New Plymouth and Wellington, or in the high country.

The average number of days in which air temperature at screen level falls below freezing point (days of screen frost) is probably only about 10 to 12 per year in most of the area. The frosts occur mainly in June, July and August. The average and extreme dates of first and last frost each season and the average number of frosts

per year are given in Table 4. The difference between the two sets of data for Levin is due more to a change of the observation site than to any difference between the two period of records. This difference and that between Waitarere and Levin illustrate the sensitivity of minimum temperatures to slight alterations in local topography. The largest differences between the various stations are in their minimum and grass minimum temperatures.

When annual mean temperatures are adjusted to refer to a standard period (1931-1960) the resulting "normals" are as follows: Para-paraumu 55.1 deg. F, Levin 54.6 deg. F, Waiterere 54.1 deg. F.

Ground frosts are frequent in open flat sites—about 50 to 60 per year on average. From May to September they average 5 to 15 per month and they occur occasionally even in summer months in susceptible sites, i.e. in sheltered hollows into which cold air can drain. Snow is almost unknown, occurring once in 3 to 10 years depending on locality. Hail and fog are each reported about 3 to 5 times per year in the average.

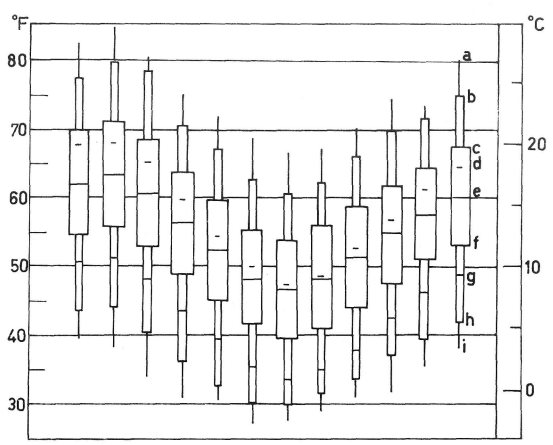

Fig. 4—Temperatures at Levin: (a) maximum, (b) mean monthly maximum, (c) mean daily maximum, (d) mean 9 a.m. soil temperature (1 ft), (e) mean daily, (f) mean daily minimum, (g) mean daily grass minimum, (h) mean monthly minimum, (i) minimum.

Sunshine, Cloud Cover, and Solar Radiation

The duration of bright sunshine and cloud cover vary over the district in a manner more or less parallel to rainfall (see Tables 1 and 2), with lowest sunshine and most clouds near the Tararua Range. The greatest sunshine amounts are near Foxton and Paraparaumu which have averaged about 2080 and 2060 hours respectively in recent years, while Levin has averaged about 200 hours per year less. The duration of sunshine as a percentage of the possible sunshine ranges from 40 per cent to 55 per cent according to the season. The average number of sunless days per year is 35 at Paraparaumu and 38 at Levin. The average amount of sky covered by clouds at 9 a.m. is 70 per cent at Levin; Paraparaumu has 5 per cent less and Waitarere 10 per cent less.

Relative humidity at 9 a.m. averages about 80 per cent over the year (75 per cent in January, 85 per cent in June and July, see Tables 1 and 2). It varies inversely to the temperature, falling to a minimum in the early afternoon (average about 65% in summer, 75% in winter).

No measurements of salar radiation are made in the area, but the average values are probably similar to those measured at Wellington. The amount of radiation received varies greatly from day to day and from month to month in a manner more or less parallel to the duration of sunshine. At Wellington the ratio between average summer and winter values of the total radiation energy received at a horizontal surface from the sun and sky is approximately 4 to 1. The annual average is approximately 330 Langleys (calories per sq. cm.) per day. Maximum daily values on bright sunny days in midsummer reach about 800 Langleys, in midwinter less than 200 Langleys.

Local Climate of Forest Area near Otaki

This paper has been concerned so far with what can be called macroclimate—the broad-scale features of the climate in a region. This is an essential background to any study of local climate or microclimate. (Local climate is usually taken to refer to the climate of a field or hillside or valley, microclimate to the climate within an individual crop or forest stand.) Because observations are lacking, little can be said about the local climate of the Otaki site (Fig. 1) except to suggest the manner in which it probably differs from the climates represented by the Levin and Paraparaumu data.

At the site, on a slightly elevated river flat, the average annual rainfall is estimated to be approximately 45 in. The distribution of rainfall and the occurrence of dry spells and droughts will be practically as at Otaki. Temperatures will be similar to those of Levin and Paraparaumu. The wind regime will be in between those illustrated for Paraparaumu and Shannon (Fig. 2). It will

probably more nearly resemble that for Paraparaumu, differing mainly in having more northwesterlies and westerlies and fewer northerlies and northeasterlies, with perhaps a tendency towards southeasterlies instead of southerlies. Occasional strong southeasterlies probably blow across the area from the Otaki Gorge.

Measurements from standard climatological installations provide a uniform basis for comparison between contrasting regions, and are a valid datum level for specifying atmospheric parameters near to but above the canopy level of most pastures and crops. They can be used directly in agricultural investigations, but they are not so relevant to the conditions within a tall forest. It is at or within the canopy layer of the vegetation that the major interchanges of moisture and energy to and from the atmosphere take place. These interchanges not only have a significant place in the study of atmospheric circulations, but they are also of equal importance to an understanding of the growth of plants in respect of transpiration, respiration and photosynthesis. In forests the most active zone for these interchanges is the canopy top, generally far above the level at which meteorological observations are customarily made. In New Zealand, unfortunately, there have been few meterological measurements made within forests, and very few indeed in or near the canopy.

Reference

Robertson, N. G. 1959: The Climate of New Zealand. *In* "A Descriptive Atlas of New Zealand". Government Printer, Wellington.

TABLE 1 — Climatological Data, Levin Horticultural Res. Stn

Based on observations 1949-60 unless otherwise stated. Lat. 40°39'S., Long. 175°16'E., Alt. 100 ft.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature (degrees F)													
Mean	62	63	61	56	52	48	47	48	51	55	58	60	55.2
Mean daily maximum	70	71	69	64	60	55	54	56	59	62	64	67	62.5
Mean daily minimum	54	56	53	49	45	41	40	41	44	47	51	53	47.8
Mean daily range	16	15	16	15	15	14	14	15	15	14	13	15	14.7
Mean daily grass minimum	50	51	48	44	39	35	34	35	38	42	46	49	42.6
Mean monthly maximum	77	80	78	71	67	63	61	62	66	70	72	75	80.9
Mean monthly minimum	44	44	40	36	33	30	30	31	33	37	39	42	28.9
Highest maximum	82	85	81	75	72	68	67	67	70	75	74	80	84.8
Lowest minimum	40	38	34	31	31	27	28	29	31	32	35	38	27.2
Mean days of max. 75.1 deg. F or over (1950-59)	3.4	5.5	3.4	0.1	—	—	—	—	—	—	—	1.4	13.8
Mean days of max. 80.1 deg. F or over (1950-59)	0.1	0.6	0.3	—	—	—	—	—	—	—	—	—	1.0
Soil temperature (1 ft.)													
Mean at 9 a.m.	67	68	65	60	54	50	47	49	53	57	61	64	58.0
Relative humidity (%)													
Mean at 9 a.m.	74	75	75	81	83	86	86	82	78	76	75	74	79
Bright sunshine (hours)													
Mean (1955-64)	204	200	172	154	116	110	111	139	149	163	171	201	1892
% of possible	46	54	47	49	40	42	40	45	44	41	41	44	45
Rainfall (in.)													
Mean (1921-50)	3.0	3.3	3.0	3.2	4.0	4.3	3.8	4.2	3.3	4.2	3.2	3.6	43.1
Number of raindays	10	11	11	13	15	14	14	14	11	14	16	14	157
Maximum daily rainfall (1896-1960)	2.2	3.0	5.6	2.0	2.8	2.0	2.7	1.8	1.6	2.2	2.2	3.1	5.6
Special phenomena (means)													
Days of snow	—	—	—	—	—	—	0.3	—	—	—	—	—	0.3
Days of hail	0.1	—	0.1	0.5	0.2	0.8	0.3	0.6	0.1	0.2	0.2	0.2	3.3
Days of thunder	0.5	0.4	0.5	0.9	0.6	1.3	0.6	1.0	0.3	0.7	0.9	0.8	8.5
Days of fog	0.5	0.4	0.1	0.9	0.4	0.8	0.5	0.5	0.4	—	0.1	—	4.6
Days of ground frost	—	—	0.2	1.5	5.2	9.8	13.9	10.2	6.2	1.5	0.2	—	48.7
Days of frost in screen	—	—	—	0.1	0.3	2.8	3.6	1.4	0.4	0.1	—	—	8.7

TABLE 2 — Climatological Data, Paraparaumu Aerodrome

Based on observations 1953-60 unless otherwise stated. Lat 40°54'S., Lon. 174°59'E., Alt. 22 ft.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature (degree F)													
Mean	63	64	61	57	53	49	46	49	51	54	58	61	55.4
Mean daily maximum	70	71	69	64	60	56	54	56	59	62	64	68	62.6
Mean daily minimum	55	56	54	50	46	42	39	41	44	47	51	54	48.2
Mean daily range	15	15	15	15	14	14	15	15	15	14	13	14	14.4
Mean daily grass minimum	50	51	48	44	40	36	33	35	38	42	47	49	42.7
Mean monthly maximum	77	78	78	71	68	62	61	62	65	69	70	73	79.8
Mean monthly minimum	43	43	40	36	32	30	28	30	32	37	39	41	27.0
Highest maximum	80	81	83	75	74	64	65	64	71	73	73	78	82.9
Lowest minimum	37	38	34	31	28	27	24	27	28	32	35	35	23.9
Mean days of max. 75.1 deg. F or over (1953-64)	2.1	4.6	3.1	0.1	—	—	—	—	—	—	—	1.1	12.0
Mean days of max. 80.1 deg. F or over (1953-64)	0.1	0.6	0.1	—	—	—	—	—	—	—	—	—	0.8
Relative humidity (%)													
Mean at 9 a.m.	75	77	77	79	82	83	85	82	77	75	77	76	79
Bright sunshine (hours)													
Mean (1953-64)	238	194	184	163	129	117	118	151	168	186	189	224	2061
% of possible	54	52	50	52	44	44	42	48	50	47	45	49	49
Rainfall (in.)													
Mean (1921-50)	2.7	3.0	2.9	3.1	3.8	3.9	3.9	4.1	3.1	4.0	2.9	3.5	40.9
Number of raindays	10	9	10	11	14	14	13	14	11	13	13	13	145
Maximum daily rainfall (1939-60)	2.4	2.6	2.8	3.0	9	2.0	2.6	3.0	2.2	1.5	2.5	3.0	3.0
Special phenomena (means)													
Days of snow	—	—	—	—	—	0.1	—	—	—	—	—	—	0.1
Days of hail	—	—	0.1	0.1	0.5	0.4	0.1	0.5	—	0.2	0.1	—	2.0
Days of thunder	—	—	0.6	0.2	0.9	0.8	0.2	0.4	0.5	0.1	0.5	0.4	4.6
Days of fog	0.1	0.2	—	—	0.1	0.1	0.2	0.4	0.1	—	0.2	0.1	1.5
Days of ground frost	0.2	0.1	0.9	3.5	5.8	10.2	14.8	11.8	8.8	2.8	0.6	0.6	60.1
Days of frost in screen	—	—	—	0.1	0.9	2.6	5.9	2.1	0.8	—	—	—	12.4
Wind													
Days with gusts 40 m.p.h. or more	5.2	4.2	5.2	4.8	5.5	7.5	7.7	5.0	6.2	7.0	6.9	6.5	71.7
Days with gusts 60 m.p.h. or more	0.9	0.5	0.3	0.4	0.5	1.2	0.9	0.2	0.7	1.2	0.9	0.6	8.3

TABLE 3 — Percentage Frequency of Surface Wind (hourly mean wind at three-hour intervals)

	03	06	09	12	15	18	21	24
PARAPARAUMU AERODROME								
Summer								
Calm	26	27	12	2	2	8	25	25
4-15 m.p.h.	60	61	69	71	70	72	62	61
16-31 m.p.h.	14	12	19	27	28	19	13	14
32-46 m.p.h.	0.4	0.3	0.6	0.7	0.8	1.2	0.5	1.0
Winter								
Calm	28	28	28	14	10	26	23	27
4-15 m.p.h.	57	57	55	66	67	56	60	58
16-31 m.p.h.	15	15	17	19	22	18	16	16
32-46 m.p.h.	0.5	0.3	0.1	0.6	0.8	0.6	0.2	0.1
SHANNON								
Summer								
Calm	62	63	35	13	8	20	55	59
4-15 m.p.h.	33	32	53	69	73	69	39	34
16-31 m.p.h.	6	4	10	19	19	12	7	6
32-46 m.p.h.	—	—	—	0.2	—	—	—	—
Winter								
Calm	72	69	65	49	37	57	65	72
4-15 m.p.h.	25	26	30	41	55	39	31	25
16-31 m.p.h.	3	3	5	10	8	4	4	3
32-46 m.p.h.	0.1	0.1	0.1	0.1	0.1	0.1	0.1	—

TABLE 4 — Screen Frosts

	Levin 1 (1906-12) (1919-29)	Levin 2 (1949-64)	Otaki (1907-28)	Wai-tarere (1959-64)	Para-paraumu (1948-64)
Date of first frost					
Average	19 May	25 Jun	2 Jun	25 Apr	1 Jun
Extreme	11 Apr	16 Apr	24 Apr	4 Apr	30 Apr
Date of last frost					
Average	12 Sep	30 Aug	28 Aug	18 Oct	29 Aug
Extreme	17 Oct	16 Oct	12 Oct	21 Nov	26 Sep
Average length of frost-free season (days)	249	298	278	189	277
Average no. of frosts per year	17	9	10	32	12