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THE RESULTANT DIRECTION AND INCLINATION OF RAINFALL AT TAITA EXPERIMENTAL STATION, NEW ZEALAND

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ABSTRACT

Resultant direction and inclination of rainfall at Taita Experimental Station, Lower Hutt, New Zealand, have been computed from vectopluviometer data for the period March 1959 to December 1971. The patterns of distribution of resultant direction and inclination are described in relation to selected daily-rainfall size classes. The relationship between resultant direction and inclination of daily rainfall are related to daily and monthly windrun data. Monthly, seasonal and annual variations of resultant direction and inclinations are described.

The implications of the distribution of the horizontal component of the rainfall from the four cardinal points of the compass are discussed.

INTRODUCTION

In order to determine rainfall direction and inclination, and the rainfall on sloping sites within adjacent catchment areas, a vectopluviometer or directional raingauge was installed during March 1959 in the climate enclosure at Taita Experimental Station (Jackson and Aldridge, 1972), Lower Hutt, New Zealand (41°11'S; 174°58'E).

Rainfall may be considered to have both direction and magnitude, and may be represented by vectors, the horizontal and vertical components of which can be satisfactorily measured with stationary directional raingauges or vectopluviometers (van Heerden, 1961). If the vector rainfall is known then rainfall magnitude on sloping sites may be estimated (Hamilton, 1954; Aldridge, 1967; Jackson and Aldridge, 1972).

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Rainfall vectors have been used in such fields as the study of bacterial blight in cotton plants (Rose and Farbrother, 1961), in investigations of raindrops and soil erosion (Ekern and Murkinham, 1947), in the design of structures that may be affected by the deviation of rain from the vertical (Lacy, 1951), in studies of the measurement of rainfall (Green, 1970), and in the preparation of an index of driving rain (Lacy and Shellard, 1962).

The measurement and application of rainfall vectors has been adequately discussed by Hamilton (1954), van Heerden (1961), Meyburgh and Wicht (1966), and locally in a catchment rainfall study by Jackson and Aldridge (1972). This paper presents and discusses resultant rainfall directions and inclinations determined over the period March 1959 to December 1971.

EXPERIMENTAL

The vectopluviometer used was similar in design to the gauge described by Hamilton (1954) and van Heerden (1961). The gauge consisted of four 127-mm-diameter knife-edge raingauge rims to measure the horizontal components of the rain, mounted vertically to face the four cardinal points of the compass and connected to four separate containers. The vertical component of the rain was measured with a 127-mm-diameter raingauge exposed with the rim horizontal, 305 mm above ground level. The vectopluviometer and vertical raingauge were checked daily at 0900 NZST, and rainfall resultant direction and inclination to the vertical calculated to the nearest whole degree for each rainday in the manner described by Jackson and Aldridge (1972).

The daily rainfalls were classified into convenient size classes and daily rainfall vectors examined in each of these classes. The raindays, i.e. days with 0.13 mm (0.005 in) or more rainfall, were divided initially into two classes, those days with vertical rainfall, i.e. measurable rainfall in the vertical raingauge only, and those days with measurable rainfall in one or more of the four horizontal gauges of the vectopluviometer. The daily vectors were grouped into 20° bearing intervals for resultant direction (001–020°, 021–040°, etc.) and 5° intervals for resultant rainfall inclination (deviation of rain from the vertical) (1–5°, 6–10°, etc.). Monthly and annual resultant rainfall vectors were determined, enabling seasonal and annual variations to be examined.

Apart from July to December 1971, all rainfall measurements were in inches. In the discussion, tables and figures, the rainfall data have been converted to millimetres.

Rainfall Size-Class Distribution

The classification of raindays into selected size classes is shown in Fig. 1a. The 25.4–50.7-mm class contributed the largest percentage of total rainfall of any single class, but comprised only 6 percent of the 2034 raindays in the period.

Days with vertical rainfall. Days with no measureable rainfall in any of the four gauges of the vectopluviometer were predominantly in the 0.1–5.0-mm size class (Fig. 1b). Of the 715 days in this class, 402 or 56 percent were days with less than 0.8 mm rainfall. The

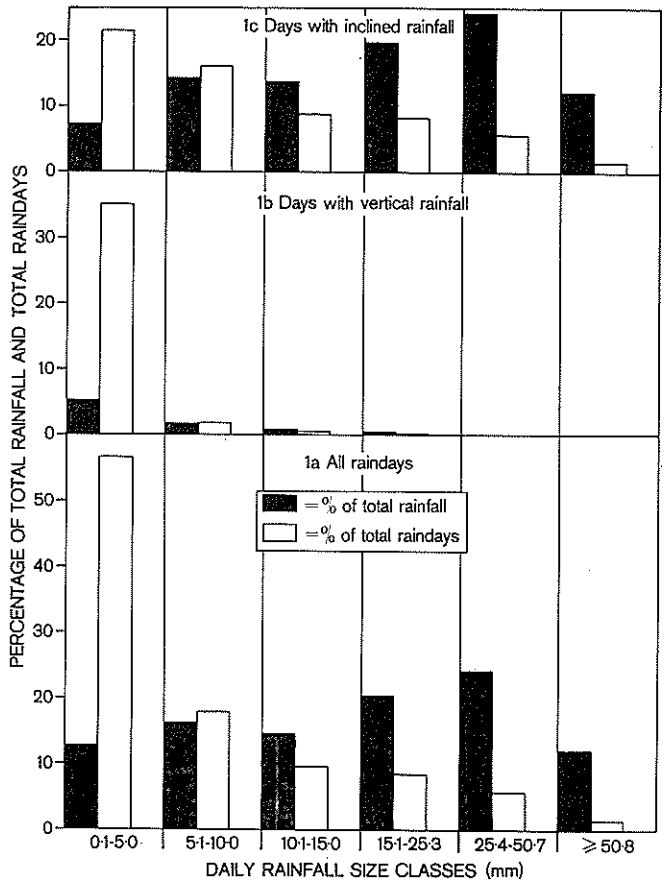

FIG. 1 — Rainfall distribution in selected size classes, March 1959 to December 1971.

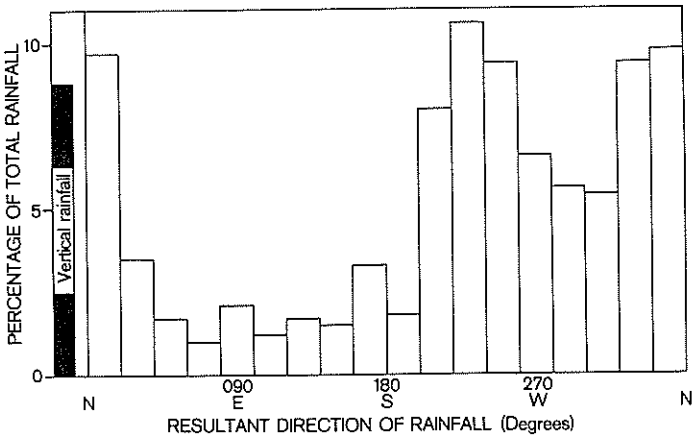

FIG. 2 — Distribution of resultant direction of rainfall as percentage of total rainfall.

largest single daily rainfall with rainfall vertical was 25.2 mm. This predominance of light rainfall on days with vertical rainfall may be accounted for either by the vectopluviometer being insensitive to light rain, or – as rainfall inclination and direction are a function of wind force and direction during the period of the rain – there may have been little wind during the rainfall.

The only windrun data available were for daily periods and not for the precise period of rain in any day, so it was not possible to determine whether these periods of light rainfall were during calm or windy conditions. However, daily windrun does give an indication of conditions over the 24-hour period of a rainday. Comparing daily windrun with raindays in the 0.1–5.0-mm class showed that the average daily windrun on days with vertical rainfall was 140 km compared with 225 km on days with inclined rainfall. The average daily windrun for all days with vertical rainfall was 138 km.

Days with inclined rainfall. Rainfall for raindays with inclined rainfall (Fig. 1c) showed the largest percentage of total raindays in any one class to be in the 0.1–5.0-mm size class. These comprise 438 or 35 percent of the 1262 raindays with inclined rainfall. The pattern of distribution of rainfall in size classes for days with inclined rainfall follows closely the pattern of distribution for all raindays (Fig. 1a).

Resultant Direction of Rainfall

Daily rainfall was recorded from all points of the compass (Fig. 2). The largest percentage of the total rainfall in any one

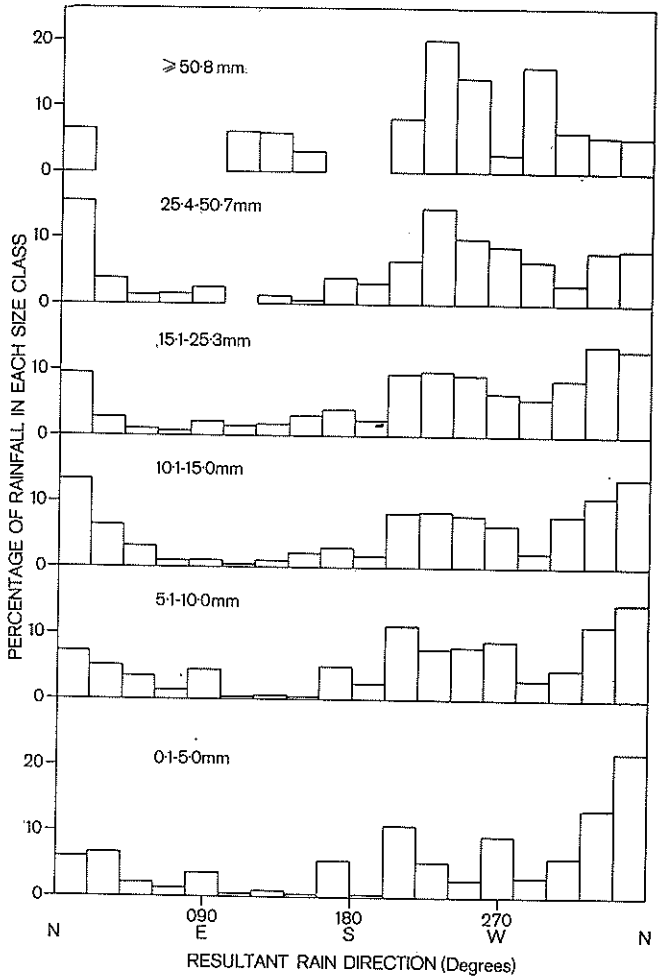

FIG. 3 — Distribution of resultant direction of rainfall in rainfall size classes.

direction class was from the southwest (220–240°) and corresponds approximately to the orientation of the lower Hutt Valley. In comparison, driving-rain roses relating wind velocity and direction with driving-rain indices (Finkelstein, 1972) show that for Wellington Airport and Kelburn, Wellington, southerly (160–200°) directions of driving rain predominate.

The distribution of the resultant directions of rainfall in relation to rainfall size classes (Fig. 3) were generally similar except for the

largest size class. Rainfall was recorded from all points of the compass in each size class, except for size classes with rainfall of 25.4 mm or greater. With increasing rainfall, resultant directions between 220° and 260° and 360° to 020° tended to become an increasing percentage of the total rainfall in each size class other than the largest size class.

Resultant rainfall directions for the 31 raindays with 50.8 mm or more rainfall were predominantly between 200° and 300°, with a marked decrease in resultant directions between 300° and 020° and an increase between 100° and 160°.

Resultant Inclination of Rainfall

The distribution of daily rainfall into 5° classes of resultant inclination is shown in Fig. 4. There were 10 raindays when identical catches in opposing gauges of the vectopluviometer, i.e. north and south, east and west, or all four, resulted in vertical resultant inclinations of rainfall, and these days have been included in the vertical rainfall blocks in Figs. 1, 2 and 4. However, the rainfall on these 10 days amounted to less than 0.5 percent of the total rainfall.

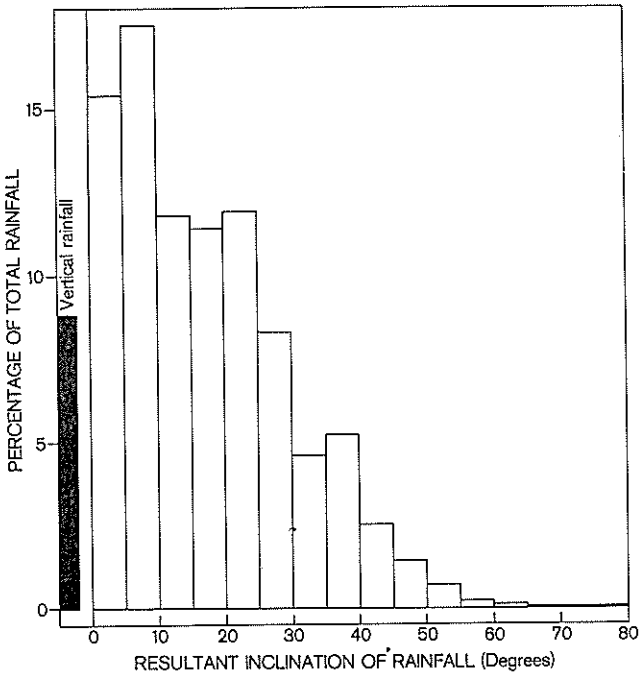

FIG. 4 — Distribution of resultant inclination of rainfall as percentage of total rainfall.

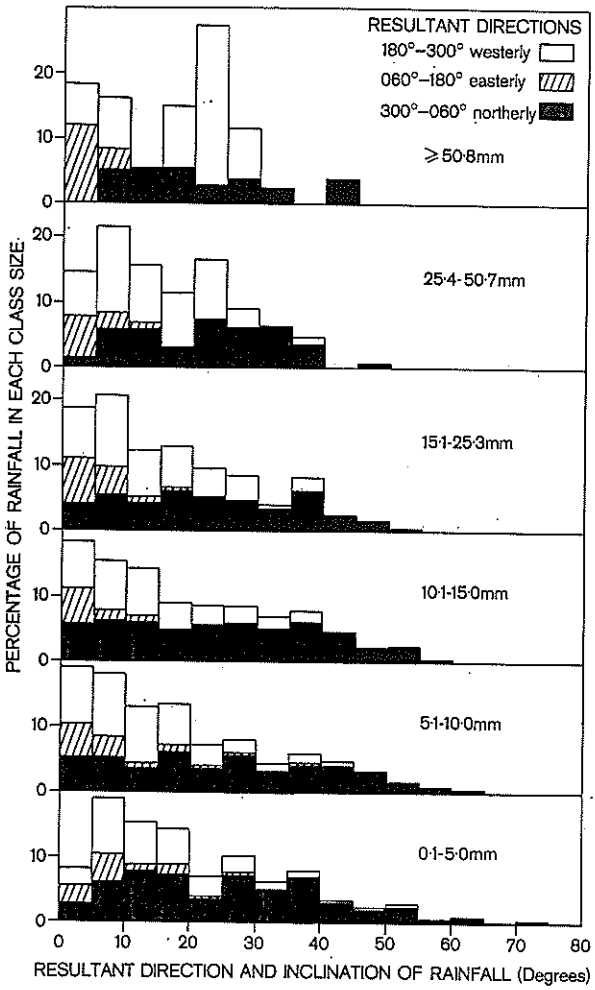

FIG. 5 — Distribution of resultant inclination of rainfall in rainfall size classes.

Examining resultant inclination of rainfall in relation to rainfall size classes (Fig. 5) showed that generally about one-third of the total rainfall in each size class fell at up to 10° from the vertical. The highest inclinations were recorded in the smaller rainfall size classes, but rainfall with inclinations greater than 45° occurred on only 48 raindays, 11 percent of the raindays in the 0.1–5.0-mm size class, and only 16 raindays, 5 percent of the raindays in the 5.1–10.0-mm class. In all but the largest rainfall size class, the percentage

TABLE 1 — Relation between resultant inclination of daily rainfall i (degrees) and daily windrun B (km/day).

Raindays				
No. in size class	*Size class (mm)*	*Linear regression equation*	*Correlation coefficient*	*Std. dev.*
438	0.1– 5.0	$i=0.078\ B+6.161$	0.595	12.1
427	5.1–10.0	$i=0.085\ B+1.118$	0.711	9.9
181	10.1–15.0	$i=0.084\ B+1.465$	0.709	10.1
168	15.1–25.3	$i=0.088\ B+1.156$	0.763	8.0
148	⩾25.4	$i=0.066\ B+1.638$	0.711	7.7

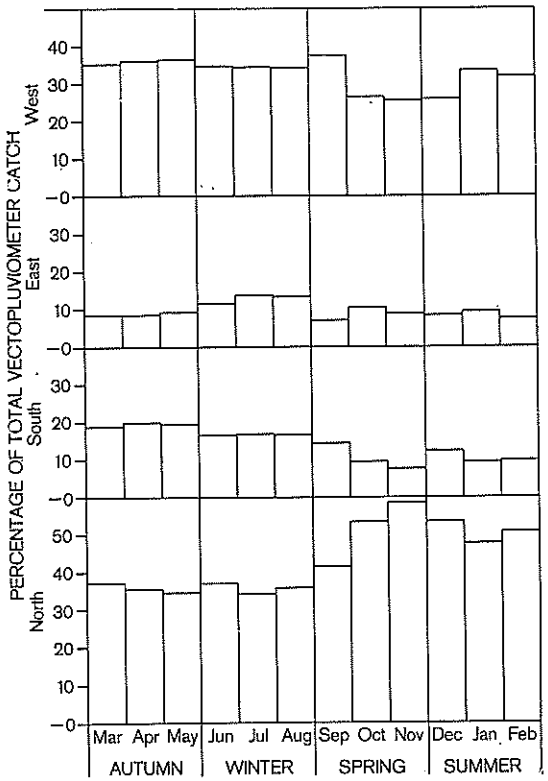

FIG. 6 — Monthly resultant direction and inclination of rainfall.

of rainfall in each 5° class of resultant inclination greater than 10° from the vertical generally decreased with increasing inclination.

To examine the relationship between resultant direction and inclination, the resultant directions were grouped into three classes, northerly, classified as 300° to 060°, easterly (060° to 180°) and westerly (180° to 300°). The 5° classes of resultant inclination were subdivided into the percentage rainfall from each of the three direction classes (Fig. 5). Easterly resultant directions were only prominent with resultant inclinations up to 5° from the vertical and were only predominant in the largest rainfall size class. Westerlies were predominant with the lower inclinations and northerlies with the higher inclinations. The inclinations at which these directions predominated were dependent on rainfall size class.

Resultant inclination and daily windrun. It was not expected that there would be a close relationship between resultant inclination of daily rainfall and total windrun for the same day, for the reason that rain may have fallen during part and not all of the 24-hour period of the windrun. Linear regression analyses of the data in each rainfall size class gave the relationships in Table 1, where i was the resultant inclination of the rainfall in degrees from the vertical and B was the daily windrun at a height of 2 m in km/day.

As indicated by the standard deviation, the largest scatter of points about the regression line was found in the 0.1–5.0-mm size class, this class also giving the lowest correlation coefficient. Although the scatter about the regression line remained large in all rainfall size classes, there was generally an improvement with increasing rainfall size class. The lower value of the standard deviation with the larger rainfall size classes may be due to the generally longer duration of the larger rainfall events.

MONTHLY PATTERN OF RESULTANT DIRECTION AND INCLINATION

Over the period 1959 to 1971 individual monthly resultant rainfall vectors were variable, although certain monthly and seasonal patterns could be seen. Combining vectopluviometer catches for each month for the whole period to give resultant vectors illustrated these trends (Fig. 6). Rainfall in spring and summer months, and especially October and November, tended more northerly than in other months. Resultant inclinations were correspondingly higher for the same periods.

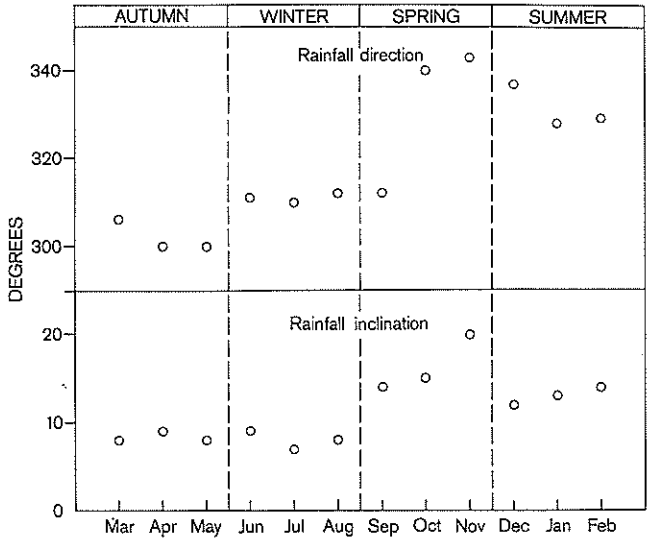

FIG. 7 — Percentage of total vectopluviometer catch in each horizontal gauge, March 1959 to December 1971.

The total monthly catch of each of the four horizontal vectopluviometer gauges, expressed as a percentage of the total catch of the four gauges combined, also illustrates this monthly and seasonal trend (Fig. 7). Spring and summer, from October onwards and more especially November, have the largest northerly component to the rainfall with October to December the smallest westerly component.

Generally, low and high monthly resultant inclinations correspond to low and high monthly mean windrun (Fig. 8). However, when individual months within the period 1963 to 1971 were considered, the relationship was not as close as Fig. 8 may suggest.

THE ANNUAL HORIZONTAL COMPONENT OF THE RAINFALL

The annual total horizontal catches in each of the four horizontal gauges of the vectopluviometer are plotted in Fig. 9, together with the total annual rainfall (vertical raingauge). The north- and west-facing gauges recorded the highest catches, and the east-facing gauge generally the lowest. At no time did the annual total horizontal catch exceed the annual total vertical gauge catch, although this may occur in individual daily events. From these data it would

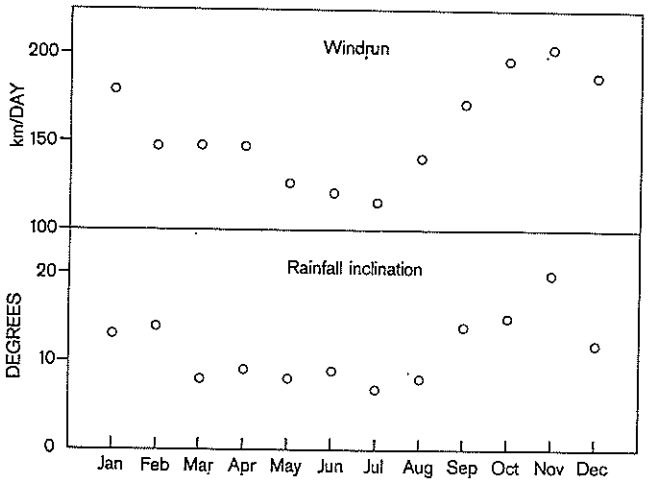

FIG. 8 — Monthly resultant inclination of rainfall and monthly mean windrun, 1963 to 1971.

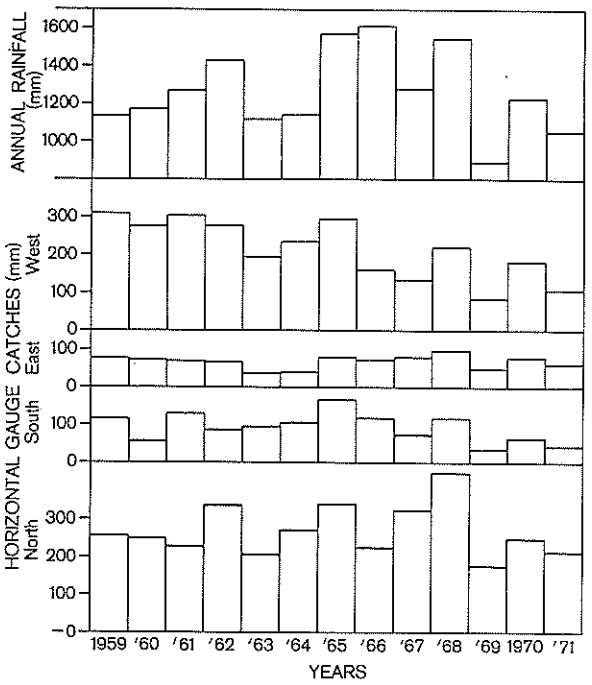

FIG. 9 — Annual horizontal and vertical gauge catches (mm).

appear that at Taita northerly and westerly exposures – i.e. hillsides, buildings, water-catchment areas – over a period of a year and longer would receive a larger proportion of the total rainfall than either southerly or especially easterly exposures. This may not be the case for individual storms or for individual months.

The annual resultant rainfall directions (Fig. 10) varied between 290° and 350°, with the years 1959 to 1966 more westerly than from 1967 to 1971. A check on the easterly and southerly components of the raindays in these years showed that up to 1966 the number of raindays with resultant directions from 180° to 269° exceeded or were close to the number of raindays with resultant directions from 360° to 089°. From 1967 onwards this trend was reversed.

Annual resultant inclinations were generally from 10° to 14° from the vertical with the exception of 1966 (5°), which also had the lowest mean daily windrun (115 km/day) in the period 1964 to 1971.

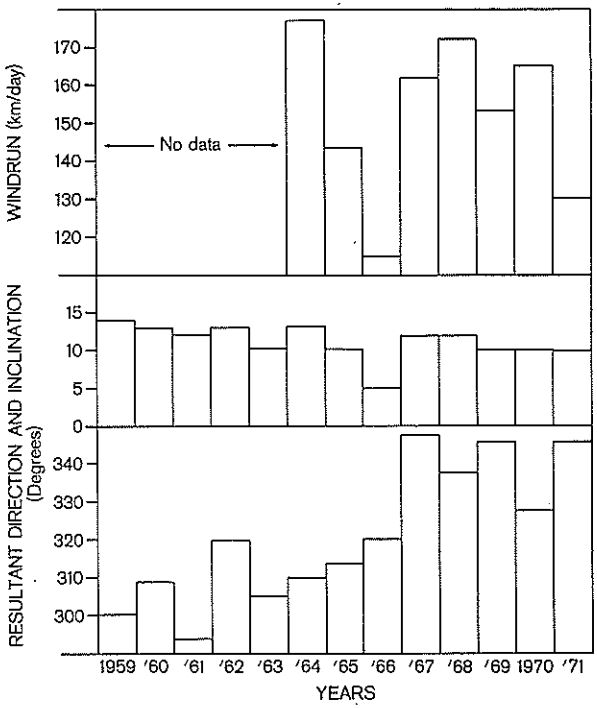

FIG. 10 — Annual resultant direction and inclination of rainfall (degrees) and mean daily windrun (km/day).

CONCLUSIONS

At the Soil Bureau, Taita, about one-third of all raindays may have only vertical rainfall, generally associated with low daily windrun, and in the 0.1–5.0-mm size class.

Daily rainfall may be recorded from all points of the compass, with the exception of daily rainfall in excess of 25.4 mm. Resultant directions of rainfall over long periods show peaks between 200° and 280° and between 320° and 020° with the largest peak, between 200° and 240°, corresponding approximately to the orientation of the lower Hutt Valley.

About 40 percent of the daily rainfall falls at inclinations less than 11° from the vertical, and about 60 percent at less than 21°. Low or high inclination of rainfall may broadly be associated with low or high windrun.

Northerly and westerly exposures receive the largest proportion of the rainfall, and easterly exposures the smallest. Generally, spring and summer months have the largest northerly rainfall components, and autumn the largest southerly and westerly components. Winter has the largest easterly rainfall component while retaining a large southerly component.

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