

MEASUREMENTS OF DEW AT A DESERT SITE IN SOUTHERN ISRAEL*

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One of the least explored aspects of desert meteorology is dew formation. Dew may play an important role in the water balance and growth regime of certain desert plants. This in turn may affect the whole desert ecosystem. Dew may also influence the occurrence of plant disease in newly developed desert agriculture (Wallin, 1967). Dew measurements in agricultural areas have been reported by Lloyd (1961), Newton and Riley (1964), and Getz (1978).

The Negev heights are a barren desert area about 400—500 m above M.S.L., located on the north to north-western slopes of the Negev mountains (Har Ha'Negev). The average rainfall in the region is about 90 mm, most of it falls during December to March. In dry years, the total annual rainfall can be as low as 25 mm. Because of the close proximity of the Mediterranean Sea (Sede Boker, in the heart of the region, is 75 km from the sea), there is moisture available in the lower atmosphere, and consequently a considerable number of dew nights.

Records of frequency of occurrence, duration, and amounts of dew in Israel are relatively scarce. Duvdevani (1974) initiated a network of dew observations for agricultural applications in Israel. Results of these observations have been summarized by Gilead and Rosenan (1954). Almost no observations exist for the Negev heights. Evenari (1971) summarized 4 years of dew observations at Avdat, about 10 km south of Sede Boker. Using Duvdevani dew blocks, he found about 180 dew nights and a water equivalent of 30 mm annually. However, with this device it is not possible to measure the dew duration or the rate of accumulation.

In order to obtain this information for the Negev heights and study the atmospheric conditions involved in dew formation, dew monitoring was started in January 1977 at the meteorological experimental site of the Institute for Desert Research in Sede Boker. In the next Section, we describe the general atmospheric and synoptic conditions conducive to dew formation in Israel. In the following Section, the instrumentation and measurement site are discussed. The results of three years of dew monitoring are presented in the last Section.

SYNOPTIC ASPECTS

Dew is basically a micrometeorological phenomenon, but it is also greatly affected

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by large scale synoptic circulation systems. The optimal atmospheric conditions for dew formation are discussed by Neumann (1965), Monteith (1956, 1963), and others. The two basic ingredients are availability of moisture and efficient nocturnal radiational cooling. Up to a distance of about 100 km from the sea, moisture is supplied by on-shore winds. In order for dew to form, the relative humidity near the ground must be very high. This happens when a stable layer of air overlies a shallow moist layer near the ground. For maximum radiational cooling, the following conditions must obtain: 1) clear skies; 2) very light winds; 3) cold and dry air above a shallow moist layer near the ground. Good radiational cooling conditions exist throughout the year in the Negev. Here the supply of moisture is a crucial factor as we go further away from the sea.

Optimal synoptic conditions for dew formation occur throughout the year when a ridge of high pressure prevails in the mid-troposphere and causes a subsidence inversion to form in the lower layers. Moisture brought in by an on-shore wind may be trapped under this stable inversion layer. Under such conditions, the sky is usually clear and the wind light. The type of low level flow pattern associated with the upper ridge is crucial for dew formation.

As far as the low level flow is concerned, the year can be divided into four seasons. In the summer, the Monsoon low pressure area in southern Asia extends to the eastern Mediterranean in the form of a low pressure trough which prevails in the region (with some minor daily fluctuations) from mid-June to the end of September. This pressure system caused a north-westerly flow over Israel and is modified by the daily sea and land breeze circulation. The large scale synoptic flow pattern usually enhances the sea breeze. In the transition period from summer to winter (October to mid-November) high pressure ridges begin to build up over Turkey and a low pressure trough extends from the Sudan to the southeastern Mediterranean. This flow configuration causes the winds to blow from a northerly to northeasterly direction; on the average less humidity is brought inland. During the winter season (mid-November to March) migrating cyclonic storms affect the region every few days, causing variable atmospheric conditions, such as strong winds and cloudiness, which prohibit dew formation. On the other hand, rainfall increase the soil moisture and also the humidity for the lower atmospheric layers. In the transition period from winter to summer (April to mid-June) the surface flow pattern is characterized by a high occurrence of Khamsin depressions moving from Egypt eastward across Israel. Some cold lows may still affect the region at the beginning of the period. In addition, the Sudan trough extends northward toward Israel from time to time. These highly variable conditions affect different regions of Israel in different ways as far as dew is concerned (e.g. Levi, 1967).

INSTRUMENTATION AND DATA

The measurement of dew involves some inherent problems not found in other meteorological observations. The difficulty is both in the definition of dew and in its actual measurement (Noffsinger, 1965; Nagel, 1962). In the literature (e.g. Noffsinger, 1965), dew is classified into several categories based mostly on the source of moisture (soil, atmospheric etc.). Since this distinction is not easily made in practice, it was decided in our case to define dew as any moisture, different from falling raindrops, which accumulates during the night on non-hygroscopic objects as a result of radiational cooling. In most cases of dew in the desert, the source of

moisture is atmospheric. Thus the desert offers an excellent environment for the study of pure atmospheric dew.

Nevertheless, on some occasions during the rainy season, when the soil is wet, an additional source of dew water is, probably, the moist soil (Lloyd, 1961). Another form of dew is that resulting from the interception of fog droplets by the receiving surface of the dew gauge. There is no method of distinguishing this type of dew deposit from the pure type of condensation due to radiational cooling.

The instrument used in this study is a Hiltner dew balance manufactured by Lambrecht. In the original instrument, the receiving surface is made of a thin nylon mesh. The thinness of this mesh prohibits it from cooling radiationally below the ambient air temperature because of a sensible heat flux from the air to the mesh. Thus on nights with light dew, the original instrument does not record any dew at all. This fact was verified during the first 6 months of dew monitoring from January-June 1977. Because of this problem, it was decided to modify the receiving surface of the dew balance by adding a plastic disc 0.2 mm thick on top of the original nylon mesh. After this modification was made, dew was recorded by the instrument whenever

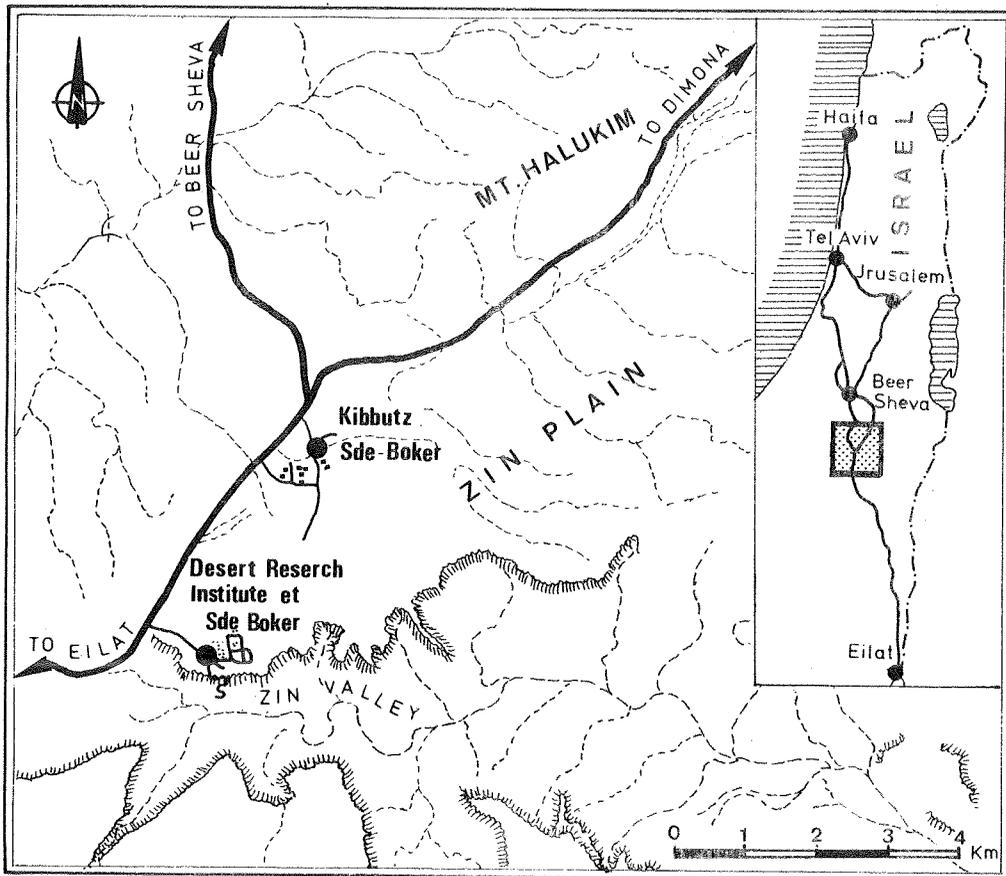


Fig.1 : The Study Area

dew was observed on nearby objects.

The instrument is located on bare loess soil in the meteorological observation site of the Institute for Desert Research. This plot is located on the northeasterly corner of the Sede Boker campus in Sede Zin, 45 km south of Beer Sheva, 480 m above sea level (Fig. 1).

RESULTS AND DISCUSSION

Procedure

The original data consisted of weekly charts on which the weight of the dew deposit is continuously recorded as a function of time. The initial processing of the charts consisted of:

- 1) Counting the number of dew events, n , per month;
- 2) Reading off the peak weights of dew water, w_i , and converting them into a depth equivalent, d_i , for each dew event. If several peaks occurred during the event, the higher one was selected from these two basic quantities. The total dewfall per month was calculated by

$$D = \sum_{i=1}^n d_i. \quad (1)$$

- 3) Measuring on the Charts the total number of hours, h_i , for which dew was increasing or stayed unchanged, and summing up for each month:

$$H = \sum_{i=1}^n h_i. \quad (2)$$

The quantity H is the total monthly dew duration. The time lapse from the beginning to the end of dew evaporation after sunrise or during the night was not measured.

Using the above three basic parameters, n , D , and H , for each month we derived three more quantities:

- 1) The average dewfall per dew event: D/n
- 2) The average duration of dew event: H/n
- 3) The average rate of dew accumulation D/H .

The above six quantities were obtained for each month from July 1977 to November 1979. Finally, the average of the individual values of these quantities for every month of the year was obtained. This operation is denoted by an over-bar ($\bar{\quad}$). For the months December through June two months are available (in 1978 and 1979), and for July to November three months are available (in 1977, 1978, 1979). These results are summarized in Table 1.

Total monthly dew amounts and dew nights

The mean total monthly dew accumulation, D , is shown in Fig. 2. Two main features stand out-- the existence of two main maxima, and the existence of two minima. The summer maximum occurs in September, and the winter and absolute maximum in December. The minima are found in April and November.

The summer maximum can be easily explained by the existence of the prevailing moist northwesterly flow over the eastern Mediterranean. The fact that the maximum occurs in late summer and not in mid-summer can be explained by the increased length of the nights in late summer. The pronounced minimum in spring can be explained by the frequent occurrence of Khamsin depressions. Similarly, the less pronounced minimum in the fall is related to the development of the Sudan trough which causes frequent dry easterly flows in the region.

Table 1: Average monthly dew statistics for the period July 1, 1977 to November 30, 1979.

	\bar{n} (days)	\bar{D} (mm)	\bar{H} (hours)	$\overline{D/n}$ (mm/day)	$\overline{H/n}$ (hour/day)	$\overline{D/H}$ (mm/hour)
January	18.5	2.22	173.0	0.117	9.4	0.0126
February	11.0	1.19	93.0	0.103	8.4	0.0123
March	10.0	1.18	76.0	0.108	7.2	0.0149
April	8.0	0.56	50.0	0.069	6.3	0.0109
May	14.0	1.05	80.0	0.075	5.6	0.0136
June	14.0	1.09	81.5	0.077	5.7	0.0137
July	16.7	1.34	90.0	0.084	5.4	0.0157
August	22.7	1.86	139.3	0.081	6.2	0.0134
September	24.7	1.91	143.7	0.077	5.8	0.0132
October	18.6	1.77	150.3	0.096	8.2	0.0118
November	15.0	1.21	106.0	0.081	7.0	0.0117
December	16.0	2.44	160.0	0.153	10.0	0.0152

One possible explanation for the winter maximum is the increased relative humidity in the atmosphere which is partly a result of evaporation from the soil after rain. More on this subject will be given in the last section. In general this result is consistent with Evenari (1971), but he found one main maximum in November and minima in December and April. This inconsistency may be attributed to the different periods of analysis and to the different locations, which, though only about 10 km apart, may have different dew regimes.

The distribution of the number of dew nights per month, n , is shown in Fig. 3. The features of this diagram are quite similar to those of Fig. 2: the locations of the maxima and the minima are almost the same, but the summer maximum is more pronounced than the winter maximum, and the winter maximum has shifted from December to January. The fact that the summer maximum is more pronounced than the winter maximum can be explained by observing that in the summer, regular northwesterly flow exists almost every day, bringing moisture from the Mediterranean, while in the winter there is a variable circulation.

Another quantity which can be derived from the data is the average dew deposit per dew night, D/n , of each month. This is shown in Fig. 4. This quantity behaves rather differently from D and n (Figs. 2 and 3). On the one hand we notice the existence of a winter maximum and a summer maximum and also spring and fall minima. On the other hand, the differences between maxima and minima in this parameter are not as large as in D and n . Furthermore, the most striking feature of this diagram is the appearance of what is essentially a summer and winter regime, separated by two transition periods in spring and fall.

The amount of dew per dew night is larger in the winter season, probably because of the longer nights, but possibly also because of increased moisture supply near the ground due to rain. The winter regime with high dew deposits per dew night, prevailing in December-March, coincides very well with the four most rainy months.

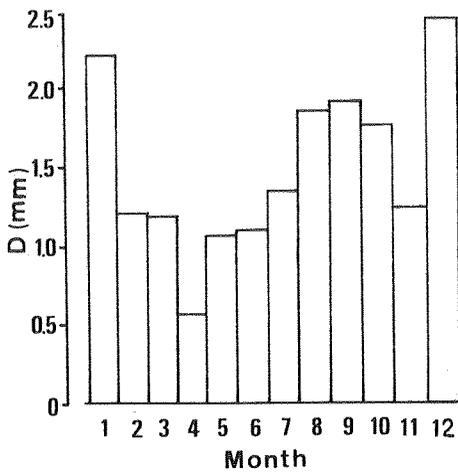


Fig. 2: Total monthly dew amounts

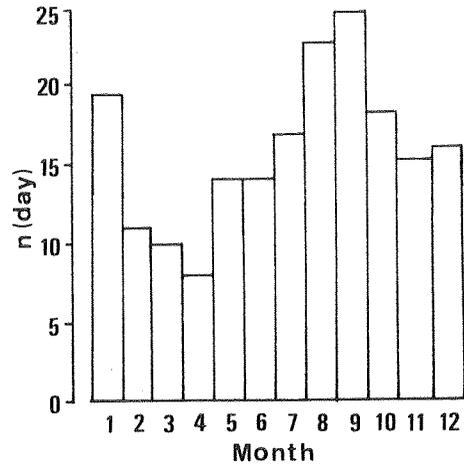


Fig. 3: Total monthly number of dew events

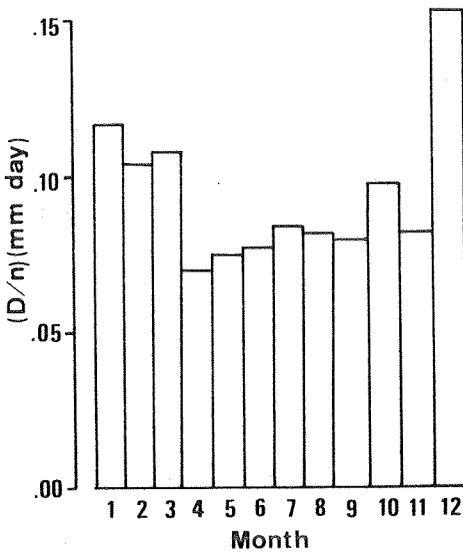


Fig. 4: Monthly average dew per dew events

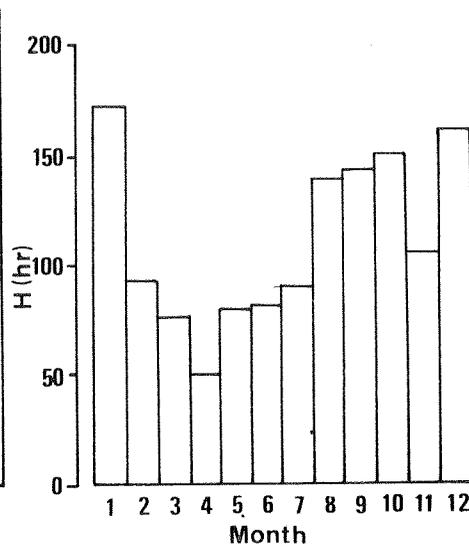


Fig. 5: Total monthly dew hours

Dew Duration

The average dew duration per month, H , was determined from the original charts as described earlier. It is interesting to compare this quantity (Fig. 5) with the number of dew nights, n , and total dew amounts shown in Figs. 2 and 3, respectively. The

behaviour of this quantity retains the main features of Figs. 2 and 3. However, the length of the fall minimum in Fig. 5 has shrunk to only one month, so that the summer and winter maxima, almost merge into one flat maximum extending from August through January. On the other hand, the spring minimum has become longer and flatter, and also extends over a 6 month period. Thus, with respect to the total monthly dew hours, the year appears to be divided into two halves; first, the 6 months of August through January, averaging about 145 dew hours per month, and second, the 6 months of February through June, averaging about 80 dew hours per month.

From the point of view of dew duration the dry season from May to October is clearly divided into an early part consisting of the months of May through July, totaling about 84 dew hours per month or about 2.7 hours per night. On the other hand, the dry months of August through October have an average of 144 dew hours per month, or about 4.7 hours per average night. This finding may have important implications on the growth regime of some desert plants and on insects or other animals that feed on them.

Dew duration per night and rate of accumulation

From the above data we calculated the average duration per dew night for each month (Fig. 6). This quantity, H/n , is affected by two principal factors, the length of the night and atmospheric and soil conditions. In the following discussion, it is assumed that if dew duration per night is positively correlated with the length of the night in the month, astronomical factors predominate over atmospheric factors. If such proportion does not exist, atmospheric factors predominate. In Fig. 6 there is a pronounced maximum of dew duration in December (10 hours per dew event) and a minimum in July (5.4 hours per dew event). Clearly, there is a good correlation between dew duration per dew event and the length of the night in the corresponding month. This means that the astronomical factor has considerable weight in determining dew duration. On the other hand, recalling that the length of the night in December and July is 14 and 10.2 hours respectively, and observing that usually dew starts to evaporate shortly after sunrise, we note that in December dew forms about 4 hours after sunset while in July dew forms about 5 hours after sunset. This statistic can be interpreted as meaning that on dew events in early winter atmospheric conditions are more favorable for dew formation than in early summer. These favorable conditions may be increased atmospheric moisture on the one hand (probably due to soil moisture evaporation), and frequent calm nights on the other. In early summer there appears to be an ample supply of moisture from the sea breeze reaching Sede Boker in the early afternoon (around 14:00 local time). The sea breeze at this time of the year is usually combined with a moderate northwesterly pressure gradient which enhances its force and causes it to blow through the afternoon and well into the evening. Usually the wind starts to subside after 21:00 or even later. Thus, dew does not start to form until midnight. On calm winter nights, dew may form very soon after sunset.

The most interesting quantity from the point of view of the microphysics of dew is the monthly average rate of dew accumulation, D/H , shown in Fig. 7. This quantity represents the quality of atmospheric and soil condition pertinent to dew formation. The behavior of D/H , contrary to the parameters already discussed, does not show marked peaks or lows. The general feature of this figure is a rather uniform average

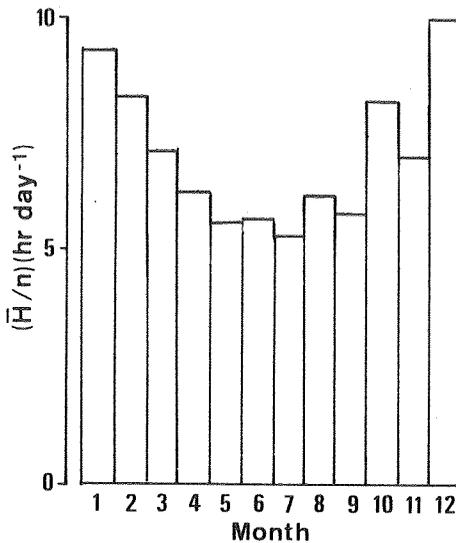


Fig 6: Monthly average number of dew hours per dew event

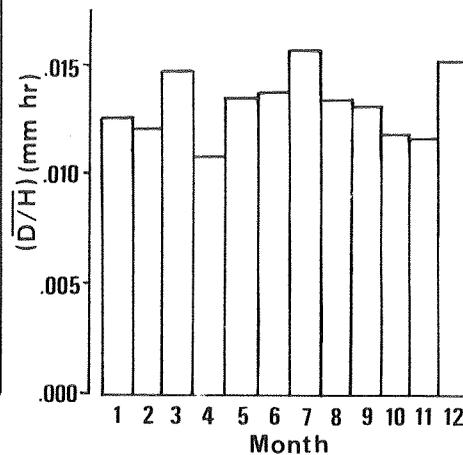


Fig 7: Monthly average dewfall rate

rate of dew accumulation throughout the year. On closer examination three peaks and three lows can be identified (although due to the short period of observations they may not be statistically significant). The main peak of the whole year occurs in July. Assuming the soil to be practically dry (as far as the effect of its moisture content on dew formation is concerned), this peak can be interpreted as a manifestation of optimal atmospheric condition for dew formation in the month of July. The second peak, which occurred in December while the soil was considerably moist, represents an optimum combination of soil and atmospheric conditions for dew formation. Despite the additional effect of soil moisture availability, the dew rate does not exceed that of July, presumably because the mixing ratio of water vapor in the atmosphere in December is considerably lower than in July: hence, to generate the same amount of downward moisture flux as in July, an unrealistically steep nocturnal temperature inversion would be needed.

REFERENCES

- Duvdevani, S., (1974): An optical method of dew estimation. *Quart. J. Roy. Met. Soc.*, 73, pp. 282—296.
- Evernari, M., L. Shanan and A. Tadmor, (1971): *The Negev — The Challenge of a Desert*, University Press, Cambridge, Mass.
- Getz, R.R., (1978): Dew monitoring network in the Southeast, *Bull. Amer. Met. Soc.*, 59, pp. 1150—1154.
- Gilead, M., and N. Rosenan, (1954): Ten years of dew observation in Israel, *Isr. Explor. Jour.*, 4, No. 2.
- Levi, M., (1967): Fog in Israel, *Isr. J. of Earth Sci.*, 16, pp. 7—21.

- Lloyd, M.G., (1961): The contribution of dew to the summer water budget of northern Idaho, *Bull. Amer. Met. Soc.*, 42, pp. 572—580.
- Monteith, J.L., (1965): Dew. *Quart. Jour. Roy. Met. Soc.*, 83, pp. 322—341.
- Monteith, J.L., (1963): Dew: Facts and Fallacies, *The Water Relations of Plants*, (A.J. Rulter and F.W. Wholehead, eds.), Blackwell, London.
- Nagel, J.F., (1962): On the measurement of dew, *Arch. Meteorol. Geophys. Bioklimatol. Ser. B.*, 11, pp. 403—423.
- Neumann, J., (1965): Estimating the amount of dewfall, *Arch. Meteorol. Geophys. Bioklimatol. Ser. A.*, 9, pp. 197—203.
- Newton, O.H., and J.A. Ridey, (1964): Dew in the Mississippi delta in the fall, *Mon. Wea. Rev.*, 92, pp. 369—373.
- Noffsinger, T.L., (1965): Survey of techniques of measuring dew, *Humidity and Moisture*, Edited by Wexler, Vol. II Reinhold, New York.
- Wallin, J.R., (1967): Agrometeorological aspects of dew, *Agr. Meteorol.*, 4, pp. 85—102.