EVAPOTRANSPIRATION MEASUREMENTS MADE IN HONG KONG.

FIRST REPORT

OCTOBER 1951 TO MAY 1953.

Introduction.

Thornthwaite (1948) has defined evapotranspiration as "The combined evaporation from the soil surface and transpiration from plants.... [It] represents the transport of water back to the atmosphere, the reverse of precipitation". He defines "potential evapotranspiration" (P.E.) as the amount of water which would transpire and evaporate in a particular locality if there were sufficient available for optimum plant growth as for example, in a desert irrigation project.

From measurements of water required for maximum crop yield in irrigation systems in the United States, Thornthwaite finds that when adjustments are made for variation in day length, there is a close relation between mean monthly temperature and P.E. and shows that values of P.E. calculated from it agree closely with actual values from the irrigation systems of the western United States and of Barahona in Santo Domingo. Should the formulae be generally true then simple calculations based on the normally observed meteorological elements of a locality would provide information of great value in irrigation planning.

In Hong Kong where irrigation of winter crops is unavoidable, a knowledge of water requirements for healthy plant growth is essential if best use is to be made of the limited water resources of the Colony. To determine the validity of Thornthwaite's empirical formulae for Hong Kong, a rough preliminary test was made for Island and Mainland reservoir catchment areas. Figures of rainfall and run-off during years when both were adequately measured were extracted from Water Authority records of the years 1929-39. Yearly run-off as calculated from the formulae was consistently lower than that observed, the average difference being 16%. It is probable the true difference was even higher since water losses in the catchments reduce the amount of water measured at the reservoir gauges.

It was concluded that the formulae have little application in Hong Kong, a not unexpected result since almost all the stations Thornthwaite lists as showing a close relation between actual and calculated P.E. experience dry, water deficient summers and moist water surplus winters, whereas the distribution in Hong Kong being monsoonal is just the reverse.

Installation and operation of an evapotranspirometer battery.

It was now obvious that if any reliable data on P.E. in Hong Kong were to be obtained, direct measurement would be necessary, and so it was decided to construct an "evapotranspirometer" which enables direct measurement of P.E. to be made. This instrument was developed by Thornthwaite and construction details are given by Mather (1950). In brief it consists of a vegetation soil tank so designed that all water added to the tank and all water left after evapotranspiration can be easily measured.

The simplified form of the instrument, installed at the King's Park Radio-sonde Station[x] on a flat bare hilltop in Kowloon Peninsula, is shown diagrammatically in fig. 1. Three square brick field tanks surfaced in cement plaster, each having an internal area of four square metres and a depth of 70 centimetres are set in line with their rims just above ground. To save material the central tank has a wall in common with each of the others.

[x] 22°19'N 114°10'E; 213 feet above mean sea level.

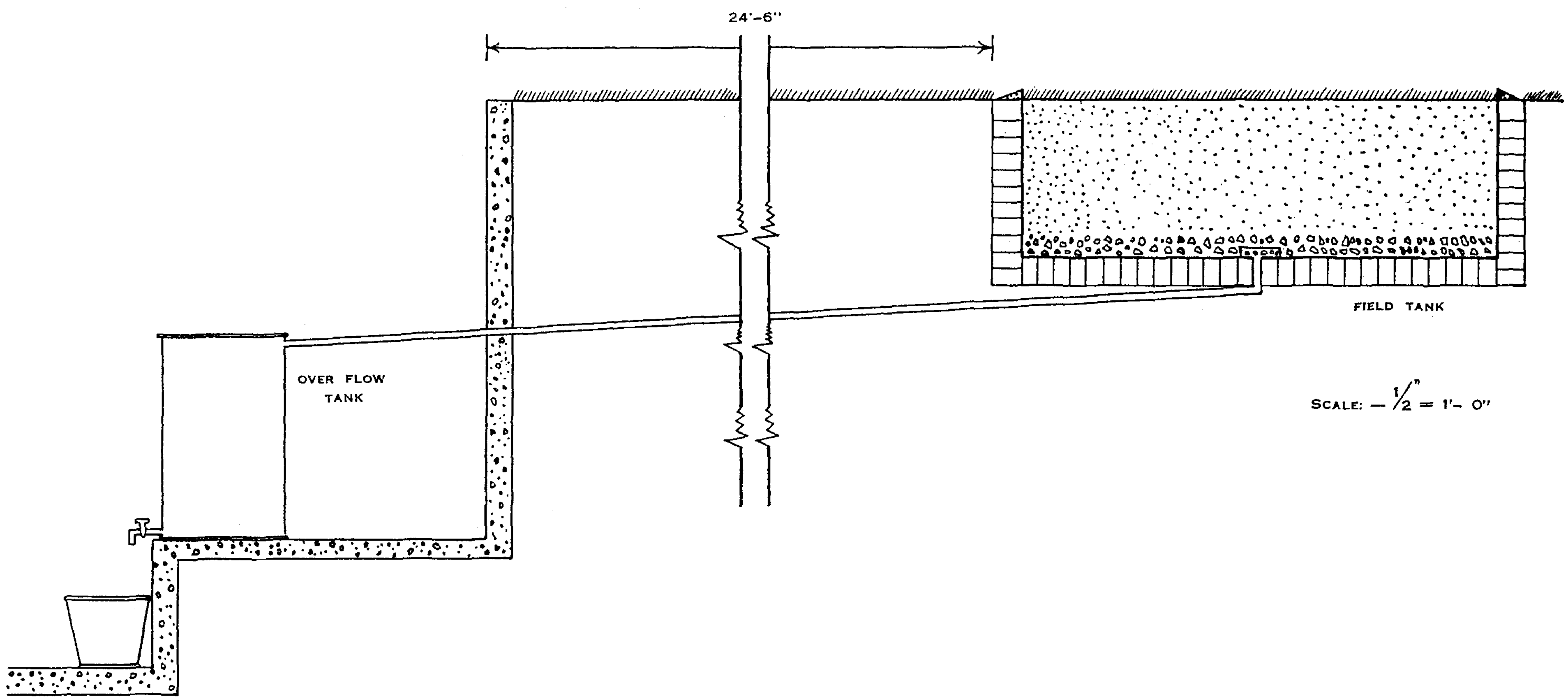

FIG. 1. CROSS-SECTION OF EVAPOTRANSPIROMETER UNIT AT KING'S PARK RADIOSONDE STATION, KOWLOON,

From the bottoms of the tanks outlet pipes lead to overflow tanks standing on a concrete step cut into the side of the Radio-sonde Hill. (By substituting brick for the steel field tanks specified by Mather, the cost of the installation was reduced from £1000 to £160). To measure the rain falling on the field tanks, a Jardi rate of rainfall recorder which has its own receiving tank stands with rim flush with the ground in a concrete pit. This and the fact that the gauge funnel is 66 centimetres in diameter ensure that the rainfall measured closely approximates that falling on the field tanks.

To avoid clogging the outlet pipes the bottom 10 centimetres of the field tanks were filled with granite chips and then to the tops with light soil turfed with local grass. (Thornthwaite in a written communication is of the opinion that a grass surface gives a generally representative measure of P.E.).

In operation, sufficient measured water is sprinkled by watering can on the field tanks each evening to ensure a small overflow the following morning, and from daily measurements of rainfall and overflow the actual P.E. for each field tank is derived since:

P.E. = Rainfall + added water - overflow

The routine is simple and requires no special training. A large bucket graduated in millimetres and a small bucket graduated in tenths of millimetres (with respect to a surface area of four square metres) are used to measure both the amount of water sprinkled on the field tanks and the yield from the overflow tanks. To reduce extraneous variations to a minimum the grass is kept cut to about two inches and the area surrounding the field tanks is turfed and well watered.

Measurements began on 1st October 1951 and were continued for a year with only grass in the three tanks. Values of P.E. for the tanks were almost identical, indicating (1) the unliklihood of leaks (2) the probability of a single tank giving representative results. This made possible the next part of the project; from October 1952 onward the middle field tank was kept in grass to act as a control, while common vegetables were grown from seedlings to maturity in the other two tanks, the P.E. of each vetetable being compared with that of grass and through this with the P.E's of the other vegetables.

Comparison of actual with calculated P.E.

Monthly values of actual (grass) and calculated P.E. for the months October 1951 through May 1953 are shown in fig. 2. These confirm the earlier conclusion that the formulae are quite unsuitable for calculating P.E. in Hong Kong and, by implication, in any monsoon climate. Since the calculated values are too low in winter and too high in summer it is probable that a humidity factor, implicit in the original formulae which applies to moist winters and dry summers, should be made explicit in any revised formulae if these are to have general validity. Equivalent catchment run-off figures derived from evapotranspirometer results for the year commencing October 1951 show calculated run-off to be 16% lower than actual; strikingly similar to the earlier figure obtained.

From fig. 2: October though by no means the warmest month has the greatest P.E., presumably because in that month dry air of continental origin first replaces the predominating moist maritime air of previous months; since spring is moist both in North America and in Hong Kong, values of actual and calculated P.E. nearly coincide then; during the summer of 1952, June and September with far more rain than the other hot months had lower P.E. One concludes from this that the more rain there is, the less is the immediate need for it in agriculture operations.

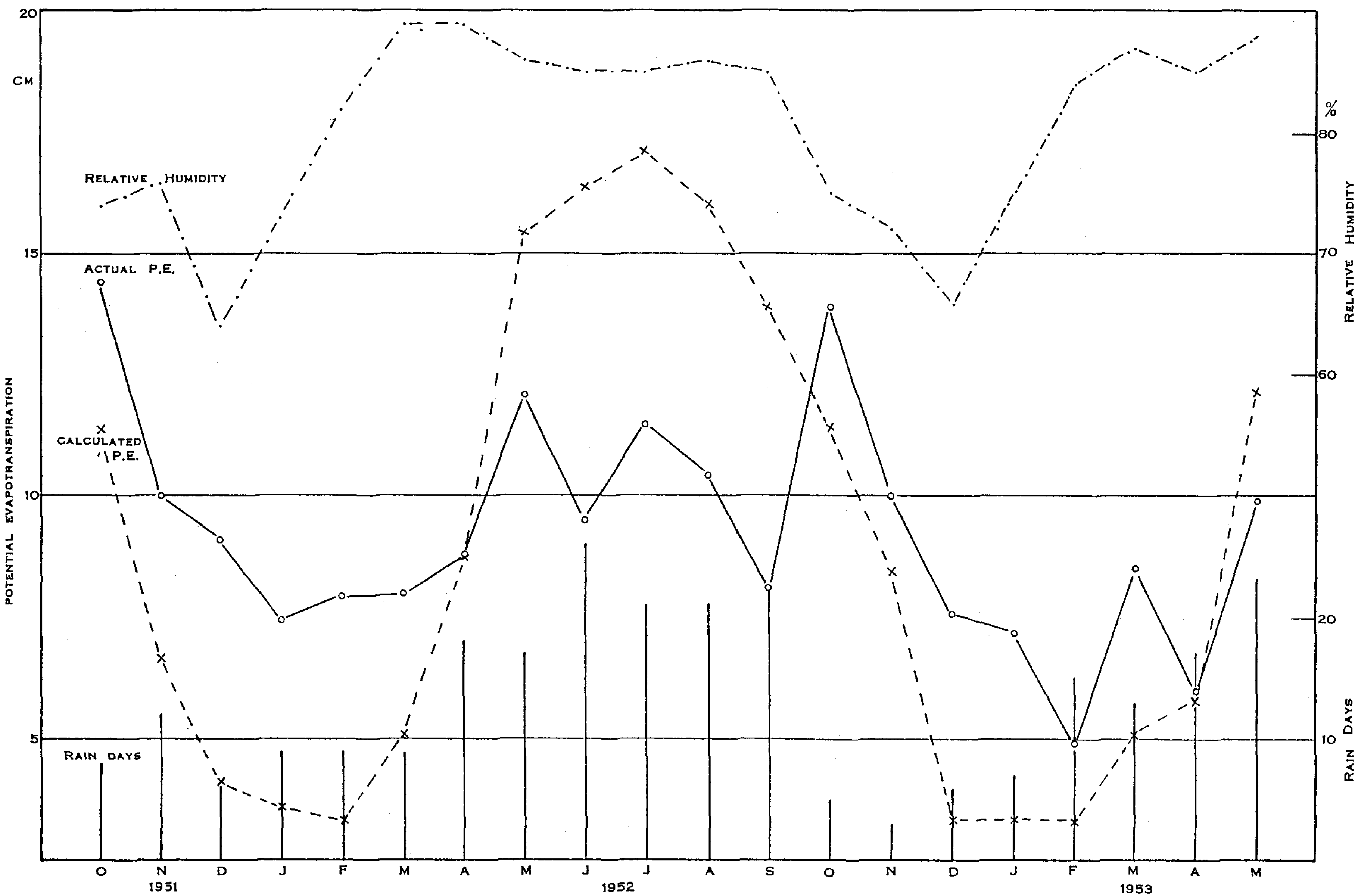

FIG. 2. ACTUAL AND CALCULATED POTENTIAL EVAPOTRANSPIRATION AT KING'S PARK.

It is too early yet to derive a new set of empirical formulae from the Hong Kong records but it is probable that these data when combined with those of other widely differing localities will form the basis of more generally applicable formulae.

P.E. of vegetables.

Most varieties of short-day vegetables usually grown in summer in high latitudes can be cultivated during the cool season in Hong Kong. In 1952-53, crops of Chinese cabbage, lettuce and tomatoes were grown from seedlings to maturity in the two outer field tanks of the evapotranspirometer battery. The daily P.E. of each crop was compared with that of the grass control tank. Thus although their growing periods did not coincide, it was possible by this means to compare the vegetables with each other and so derive significant figures of relative water needs. Results are summarised in Table 1.

Table 1. Comparisions of P.E. between vegetables and grass.

Crop	Chinese cabbage (Paak Ts'oi Sun)	Lettuce	Tomatoes
Planting date	25 Oct. 1952	18 Nov. 1952	25 Oct. 1952
Time to reach maturity (days)	24	58	31 (first fruit) 170 (last fruit)
Number of plants	90	36	26
Total crop weight (lbs)	$28\frac{1}{2}$	45	$100\frac{3}{4}$
(1) Total potential evapo-transpiration (mm)	142	267	1173
Average daily P.E. (mm)	5.9	4.6	6.9
(2) Total P.E. of grass in same period (mm)	89	159	511
Average daily P.E. of grass in same period (mm)	3.7	2.7	3.0
Ratio $\frac{(1)}{(2)}$	1.6	1.7	2.3
Mean temperature during period (^{o}F)	74	64	65

Fig. 3 shows as an example, the P.E. curve of Chinese cabbage and the P.E. control curve of grass, as well as daily mean values of temperature, relative humidity and wind. It can be seen that the regulation of P.E. is not by temperature alone for relative humidity also has a marked effect. This is especially noticeable between the 19th and 23rd days.

Fertilisers were added to the crops as required and in general yields were higher than those from market gardens. Although the site is completely exposed to the fresh or strong dry winds of winter, and the crops grown are reckoned to be particularly susceptable to wind burn, no leaf damage occurred. It seems that when there is a plentiful water supply plants can combat the desiccating effects of wind. Probably wind breaks would have reduced P.E. in proportion to leaf area and resulted in more nearly equal water use by the three vegetables and grass.

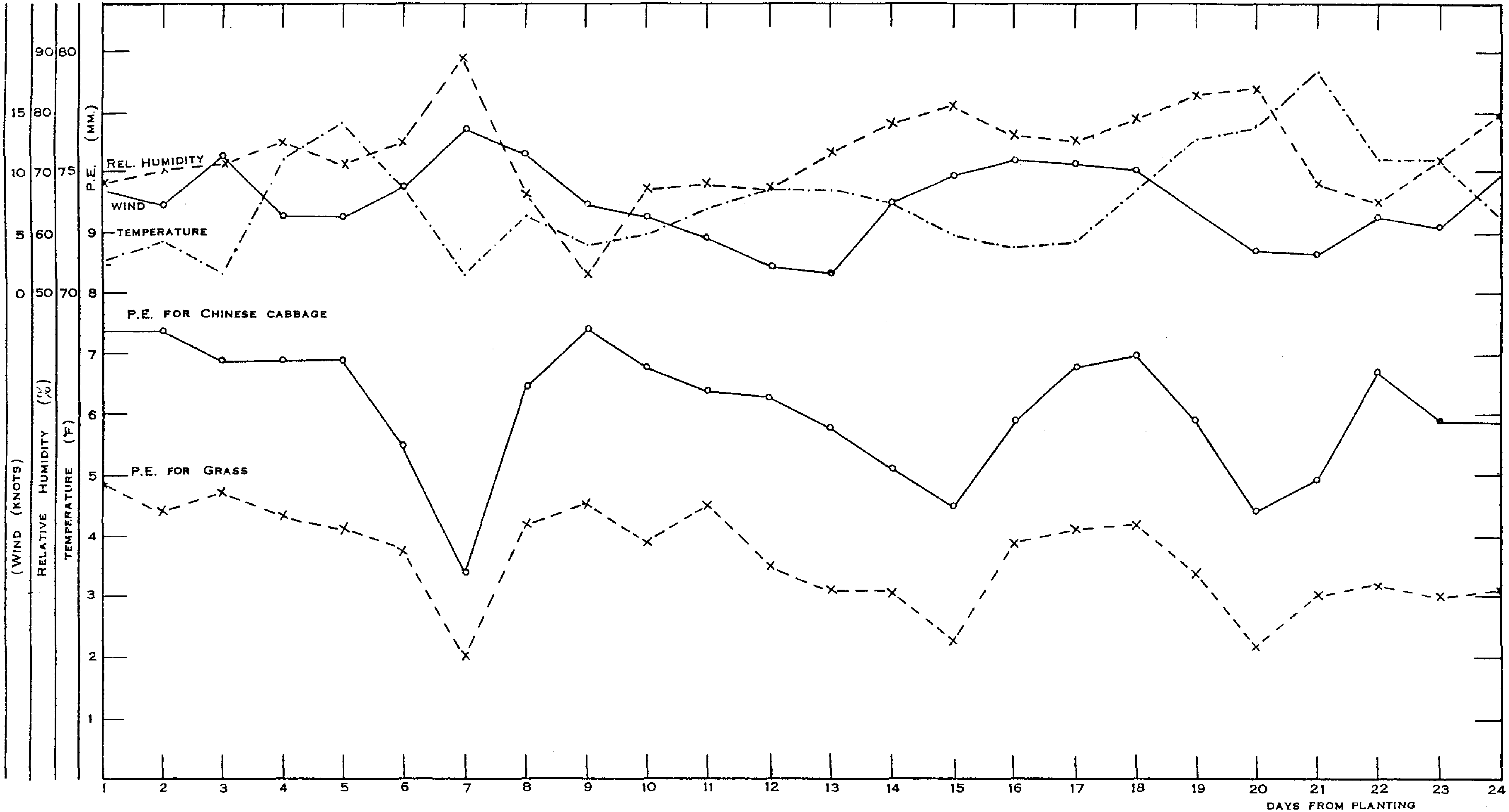

FIG. 3. DAILY VALUES OF POTENTIAL EVAPOTRANSPIRATION TEMPERATURE. RELATIVE HUMIDITY AND WIND DURING PERIOD OF GROWTH OF CHINESE CABBAGE CROP.

Acknowledgments.

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