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LATENT IMAGE FADING OF NEUTRON FILMS AT CERN

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1. INTRODUCTION

Most fast neutron personnel monitoring dosimetry systems utilize nuclear track techniques, with Kodak NTA films. It is well known that the storage properties of the latent image are a function of the humidity and temperature of the environment where the films are used[1].

While the extent of latent track fading has been extensively studied[2], the practical efficiency of various methods of protection of the film, such as sealing in some polymer-foil or metal-foil plastic compound[3,4], is still under discussion and no test data are yet available in the case of use on a large scale[5].

At CERN we have adopted the sealing method as described by Soudain and Portal[3] and we have carried out an extensive test in field conditions. By this we mean that the films were prepared exactly like the routine films, without any special precautions, and were later on developed and read among routine films, with no selective rejection or interpretation.

2. EXPERIMENTAL PROCEDURE

(a) Film packaging

The standard procedure at CERN is the following. Due to possible difficulties in the supply of the monthly films, we have normally a three months reserve, stored at 4°C with no special shielding. To reduce the background on the films, prior to packaging they are exposed for 24 hours to a 100% humidity environment and then desiccated for two days in a special cupboard with an ultimate humidity lower than 10%. At this time they are sealed in a special aluminized plastic envelope which has also been desiccated. The background at the time of reading is then less than 1 track/mm^2.

The films used for this experiment were packaged in the way described above during the preparation of the 3000 films of a monthly distribution.

(b) Radiation exposure

All the experimental films were exposed to the standard PuBe calibration source at sufficient distance and exposure time to obtain a uniform exposure; for each exposure one film was retained for immediate treatment. All the others were mixed together and distributed among the various lots. The exposure was selected in view of the best scanning conditions after development, i.e., to get about 50 tracks per mm^2.

(c) Humidity conditions

The storage temperature was kept at 20°C. Six different humidity levels were realized in sealed containers (desiccators) with a mixture of water and sulphuric acid, as shown in table 1.

Three different types of hygrometer (hair type) were used to measure the relative humidity, after calibration at zero and 100%. The values registered for the instruments were identical at ±3% in each case. During the latency period, a check for the humidity level was made every week.

When a certain lot had reached the date for development, it was left dry for 24 hours, in order to have the same treatment conditions.

(d) Scanning of the films

When developed the films were mixed with others and read, routinely as usual, by two different scanners. For each time + humidity condition the films were scanned by the two operators and the mean value was computed. When a large discrepancy was found between the two scanners, the films were reintroduced in another lot for routine measurement by both.

The routine scanning is made with a modified Leitz microscope, with an 11^{o} tilted table and automatic displacement with adjustable speed, covering a strip of 3.0 x 0.29 mm. The field is displayed by projection on a screen, with a 50 x 10 magnification.

3. EXPERIMENT No. 1

This first experiment was performed in order to verify the efficiency of the sealing technique. For each time + humidity condition, 2 lots of 3 films were compared, the first one unsealed and the second one sealed. For each humidity degree, the reference is the reading of the sealed lot corresponding to the shortest time, and the other results are expressed as a percentage of this reference. Table 2 shows these reference readings together with the corresponding values for unsealed films. These numbers could be compared with the mean value for test films developed immediately after exposure to the source,which amounts to 38.5 ± 6.2 tracks per unit area.

Figure 1 shows the relative readings as a function of time for the films sealed and kept at 14% relative humidity. Even in this case there exists a noticeable latent image fading, which we shall call the "unavoidable fading". Figure 2 shows the 82% relative humidity condition; it can be compared with the data of Soudain[3]. The fit is not excellent, and in 6 weeks time we have only 80% of the initial reading, compared with the 87% of the above author. But this discrepancy will be explained later (see 4. below). The unsealed films at 82% have of course been completely washed out in less than one week.

The next set of figures (Figs. 3-8) display for each relative humidity level the variation of the readings as a function of time for sealed and unsealed films. While the rate of fading increases very quickly with the relative humidity for the unsealed films, the curves for the sealed ones are very similar and show that the mean fading rate is more or less independent of the humidity level. But when regarding individual films in each lot, one notices sometimes that the lowest value read is far off from the expected distribution spread. This is why the experiment was repeated on a larger scale.

4. EXPERIMENT No. 2

Each lot corresponding to a given time + humidity condition includes a minimum of 15 films, prepared as explained in 2. above; in addition all the films were mixed before exposure, so that each lot is supposed to be representative of the statistical distribution of all the sealed envelopes with regard to their physical properties.

For a given humidity degree, the readings in each lot are distributed among 6 classes, equally spaced and defined at the first scanning time.

Figures 9-14 are relative to unsealed films; it is clearly seen that for each humidity level there is a shift in the whole distribution towards the lower class, with a rate increasing with the degree of humidity. From these data and the data from Figs. 3-8 one can establish table 3, giving the time for total disappearance of tracks as a function of humidity levels.

Figures 15-20 are related to sealed films; the shift with time of the initial distribution can broadly be divided into two components: a first one, very slow, for the majority of the film, and a second one where a certain number of films are going to the lower class with a speed depending on the humidity level and comparable statistically with the speeds given in table 3.

The possible interpretation of this phenomenon is that a certain percentage of sealed envelopes are in fact incorrectly sealed (either the thermal sealing of the plastic is not complete, or the envelope itself is not completely air-tight due to punctures or small defects in the coating, with various degrees of transmission of humidity inside). This should explain why certain lots (for example corresponding to 4 weeks at 100% humidity) do not follow exactly the statistical behaviour of the majority.

To confirm the validity of this assumption, let us take as reference the best values at 14% humidity, where the fading is the smallest and seems to be noticeable only after a couple of weeks (see Fig. 15). For each case (time + humidity) we discard all the values different from the corresponding reference at the same time by more than two standard deviations. These rejected values in fact, when one considers individual films, show a very low reading (0 or 1) as soon as the time reaches the time for the disappearance of tracks for unsealed films at the same humidity levels as those given in Table 3. The mean values for each lot then become as shown in table 4, and at any given time the reading seems to be independent of the humidity level. With these corrections the curve of relative readings as a function of time at 82% relative humidity as plotted in Fig. 21 shows that after 6 weeks we have a value of 88%, very close to the 87% mentioned for this type of package by Soudain and Portal[3]. In other words, the method for protection of the films against the influence of humidity works perfectly when the sealing is perfect.

However, on a routine basis for thousands of films treated one cannot guarantee this level of perfection. We have thus computed the number of rejected values in each lot, expressed in percentage of the number of films in the lot (table 5). For all time + humidity conditions on the left side of the oblique line, the percentage of films with "lost tracks" due to faulty envelopes is very low, normally zero. For the other conditions it may increase up to 50%.

The relative humidity level on the CERN site has been recorded during a period of one year; mean values range between 60 and70%. Inside the buildings and experimental halls where the films are normally stored and used, it is always lower than 50%. Consequently with a periodic exchange every 4 weeks, the maximum loss due to faulty sealing is estimated to be between 0 and 6%.

The unavoidable fading can be computed from table 4; for a 4-week period at 50% humidity it is of the order of 10%. The calibration films are irradiated 3 weeks prior to treatment together with the routine films and thus have a lower fading. Considering other possible errors involved in the dose estimate (energy response, standard deviation, the number of counted tracks in each film, conditions of use of the films, etc.), which considerably exceed the fading effect, it has been found justified not to apply any correction to allow for the fading in the present application of the neutron films.

REFERENCES

1. C.T. Meyer, Latent image fading in personnel neutron monitoring films, MLM 1490 (1962).

2. K. Becker, Photographic film dosimetry, London (1966).

3. G. Soudani and G. Portal, Fading dans les dosimètres à neutrons rapides Eastman Kodak, CEA-FAR-PAS/METROLOGIE (1961).

4. K. Becker, Progress in solid state fast neutron personnel dosimetry, IAEA (1972).

5. P. Gollon, Personnel dosimetry at accelerator laboratories, NAL-TM-608 (1975).

Table 1

Relative humidity conditions

Container No.	H_2O (ml)	H_2SO_4 (ml)		Relative humidity (measured) %
1	200	169	1.385	14
2	200	108	1.295	38
3	200	85	1.250	50
4	200	65	1.205	62
5	200	40	1.140	82
6	200	0	1.000	100

Table 2

Number of tracks per unit area at the first development

Conditions		Sealed films	Unsealed films
14%	1 week	40.0 ± 5.2	41.5 ± 8.6
38%	1 week	42.2 ± 5.7	38.5 ± 3.9
50%	1 week	35.5 ± 2.2	33.1 ± 3.2
62%	4 days	39.5 ± 6.1	39.2 ± 5.2
82%	1 day	39.7 ± 4.5	36.8 ± 4.4
100%	1 day	39.0 ± 2.7	38.0 ± 4.5

Mean value for sealed films	39.9 ± 1.41
Immediate treatment (2 h)	38.5 ± 6.2

Table 3

Total fading time as a function of humidity

Relative humidity %	Time for total disappearance of tracks
14	> 24 weeks
38	10 "
50	8 "
62	4 "
82	4 days
100	2 "

Table 4

Mean values after rejection

Time (weeks) \ Relative humidity %	14	38	50	62	82	100	Mean value
2	40.0	39.0	41.0	39.0	39.0	39.0	39.5
4	35.5	37.0	36.0	32.0	34.0	34.0	34.7
8	31.5	30.5	32.5	31.5	32.5	30.5	31.5
12	26.7	26.5	26.5	24.5	26.7	23.5	25.7
16	20.1	19.9	17.5	19.1	13.0	15.0	18.1
24	12.0	12.1	10.5	10.5	12.4	15.0	12.0

Table 5

Percentage of rejection (films with a reading lower than 2 σ)

WEEKS \ % HUMIDITY	14	38	50	62	82	100
2	0	0	0	0	20	20
4	0	0	6	15	45	20
8	0	3	6	33	45	40
12	0	3	45	33	45	40
16	0	3	50	33	45	40
24	3	26	60	33	45	40

EXPERIMENT 1

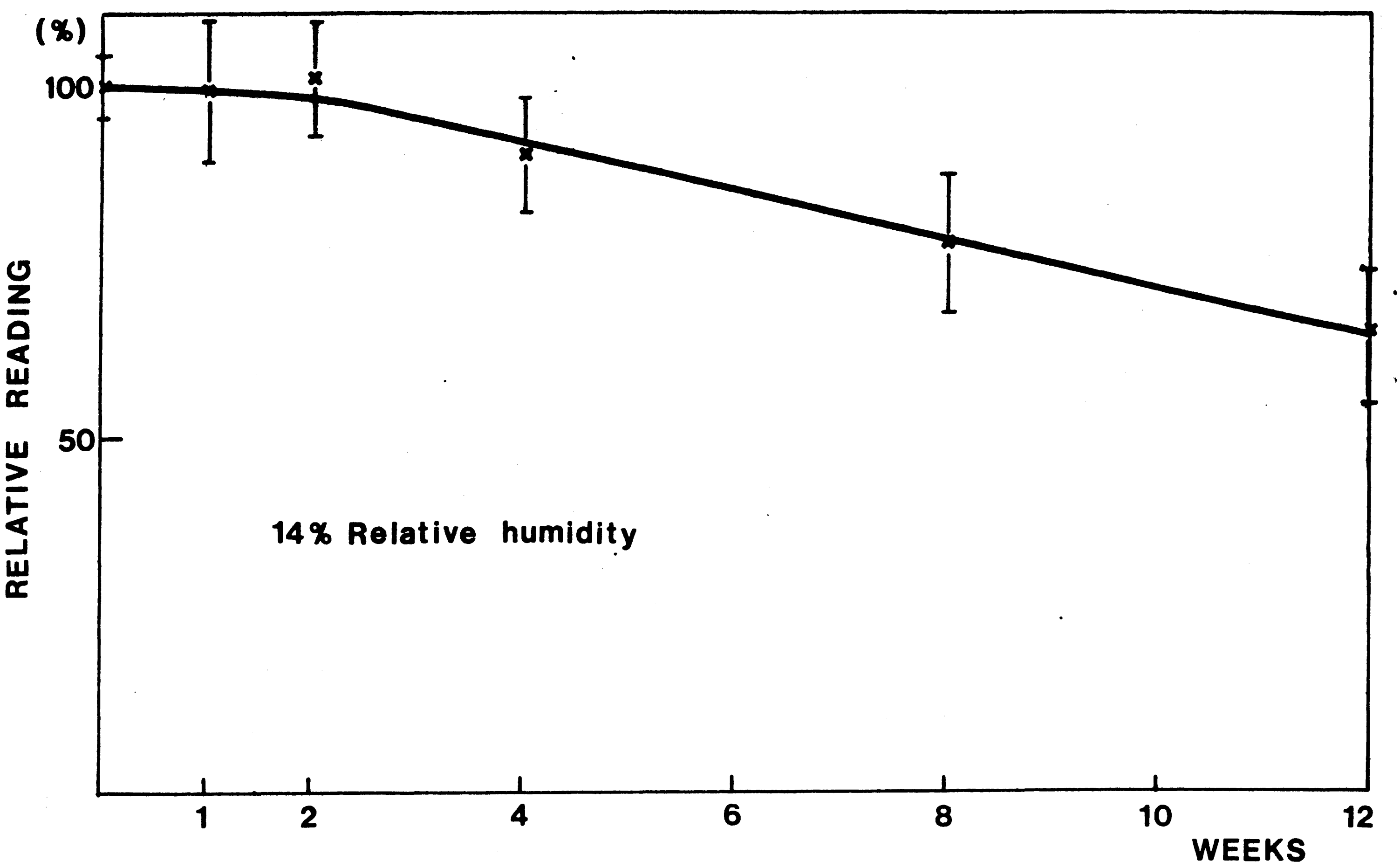


FIG.1

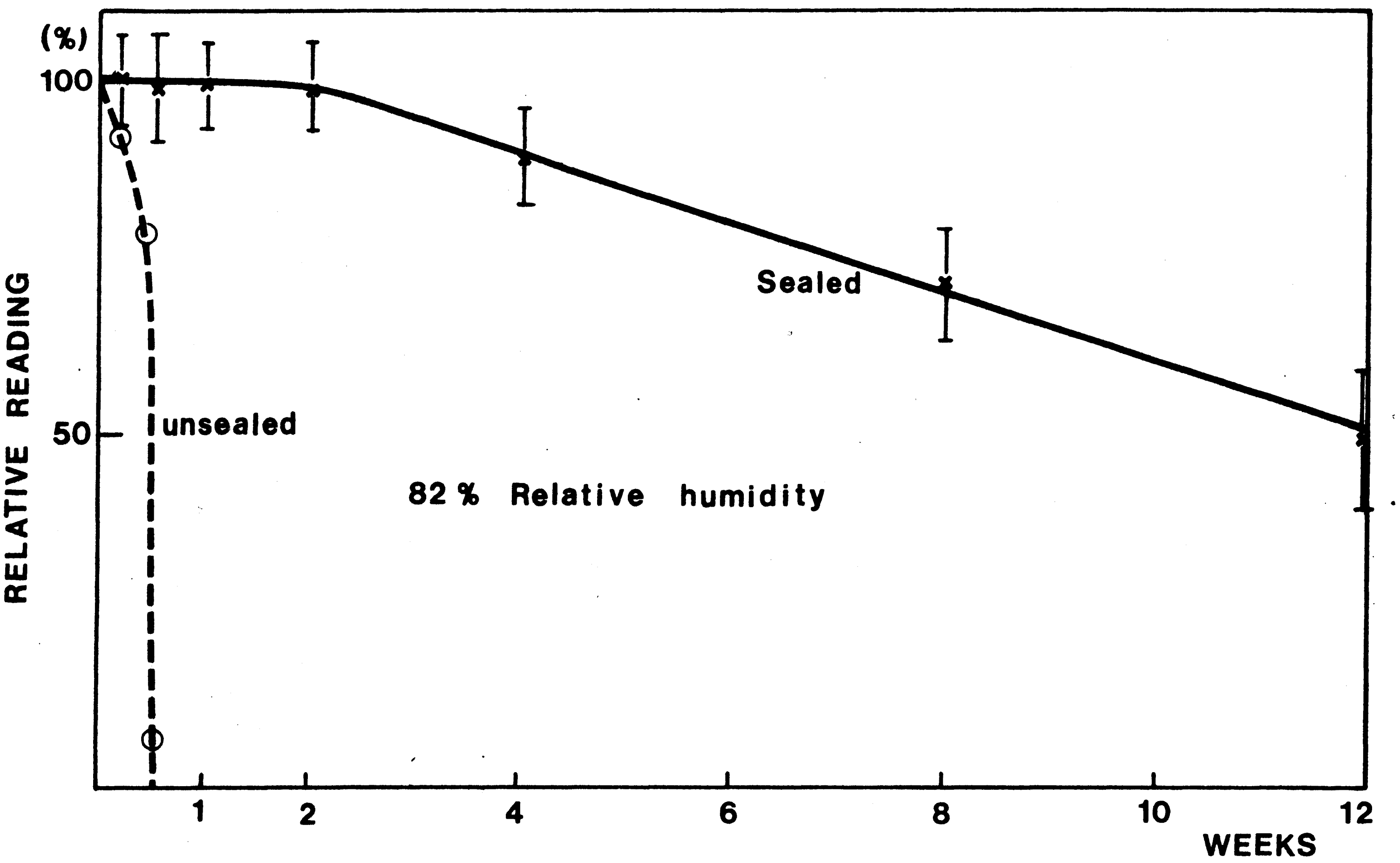


FIG.2

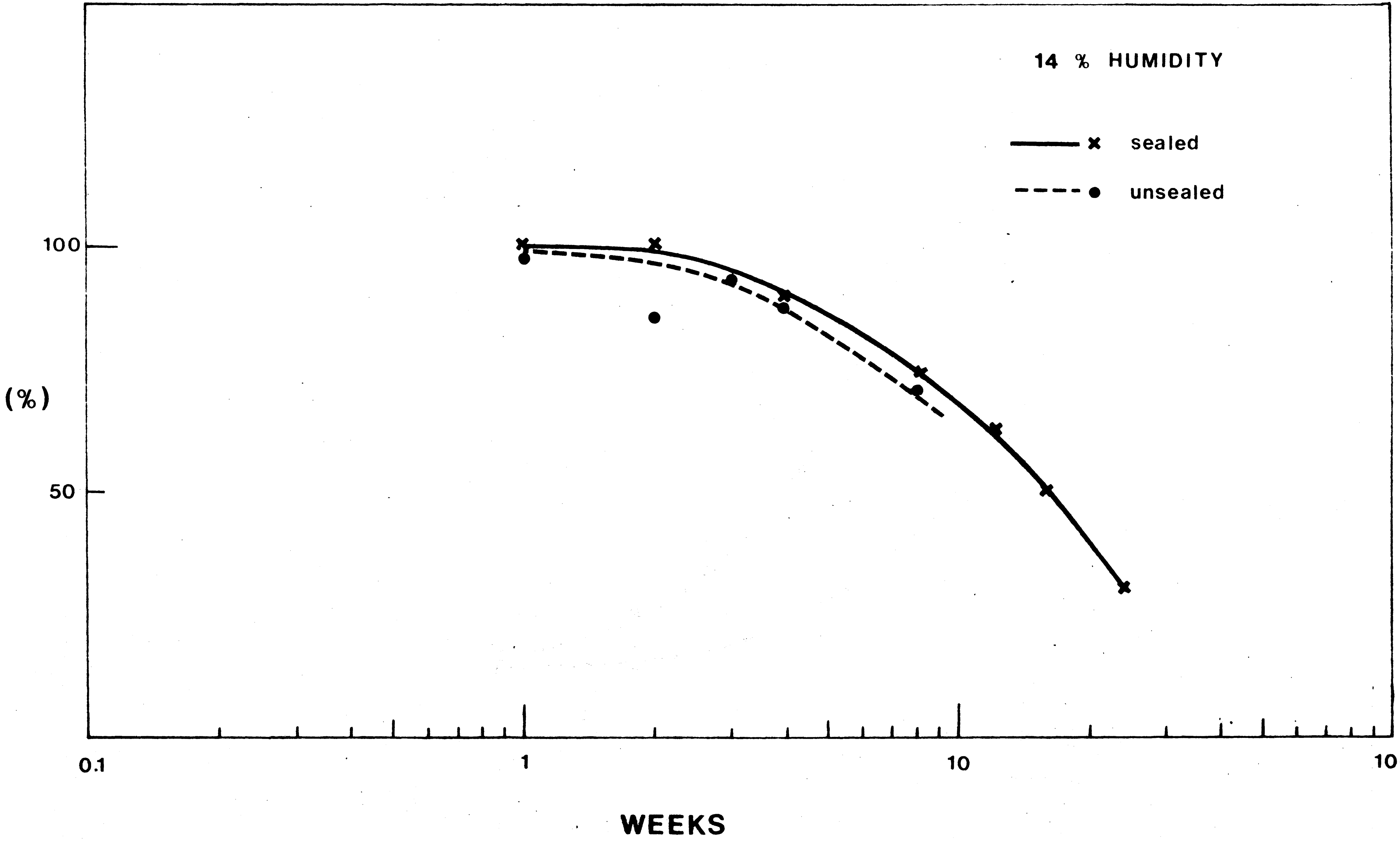


FIG. 3

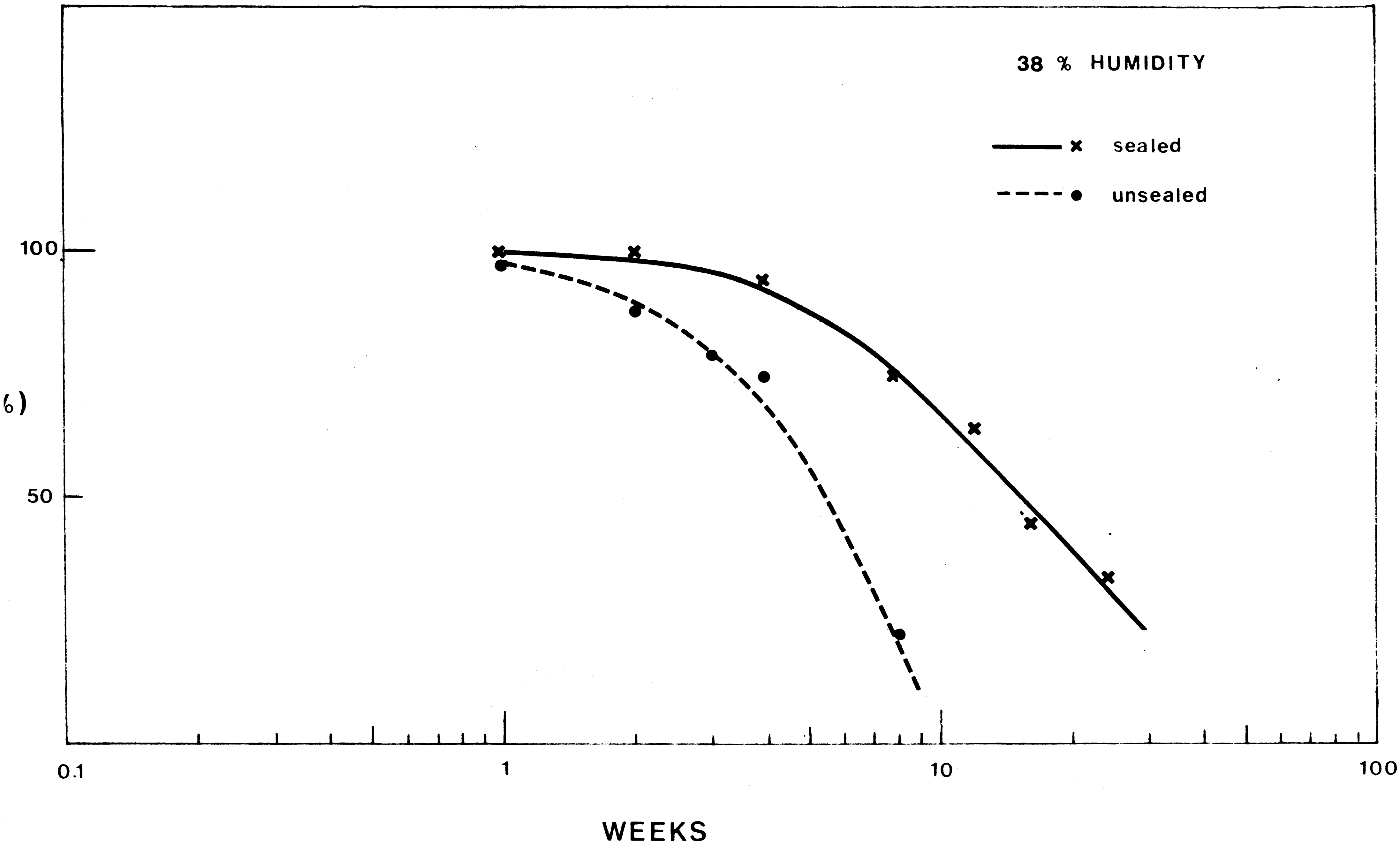


FIG. 4

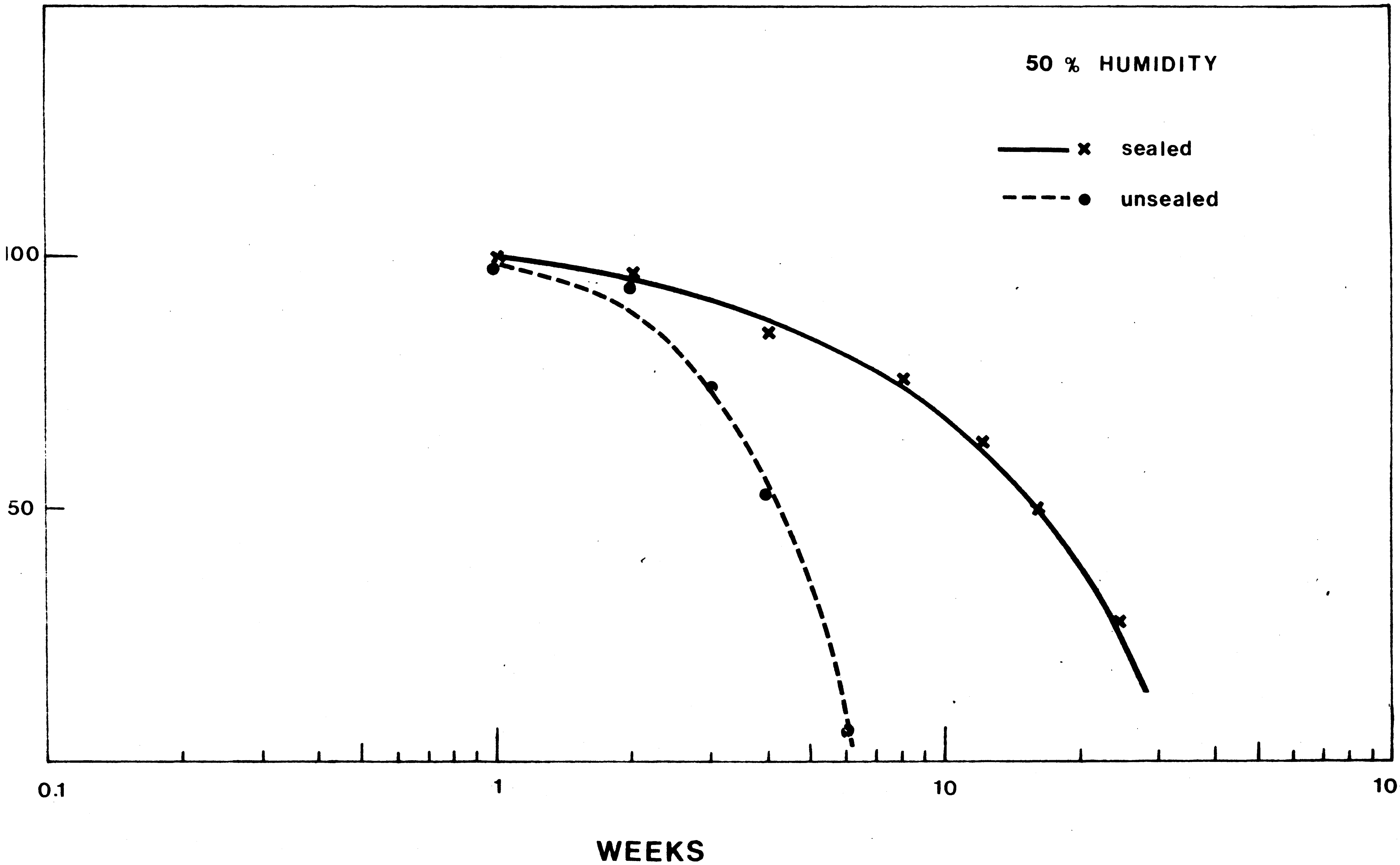


FIG.5

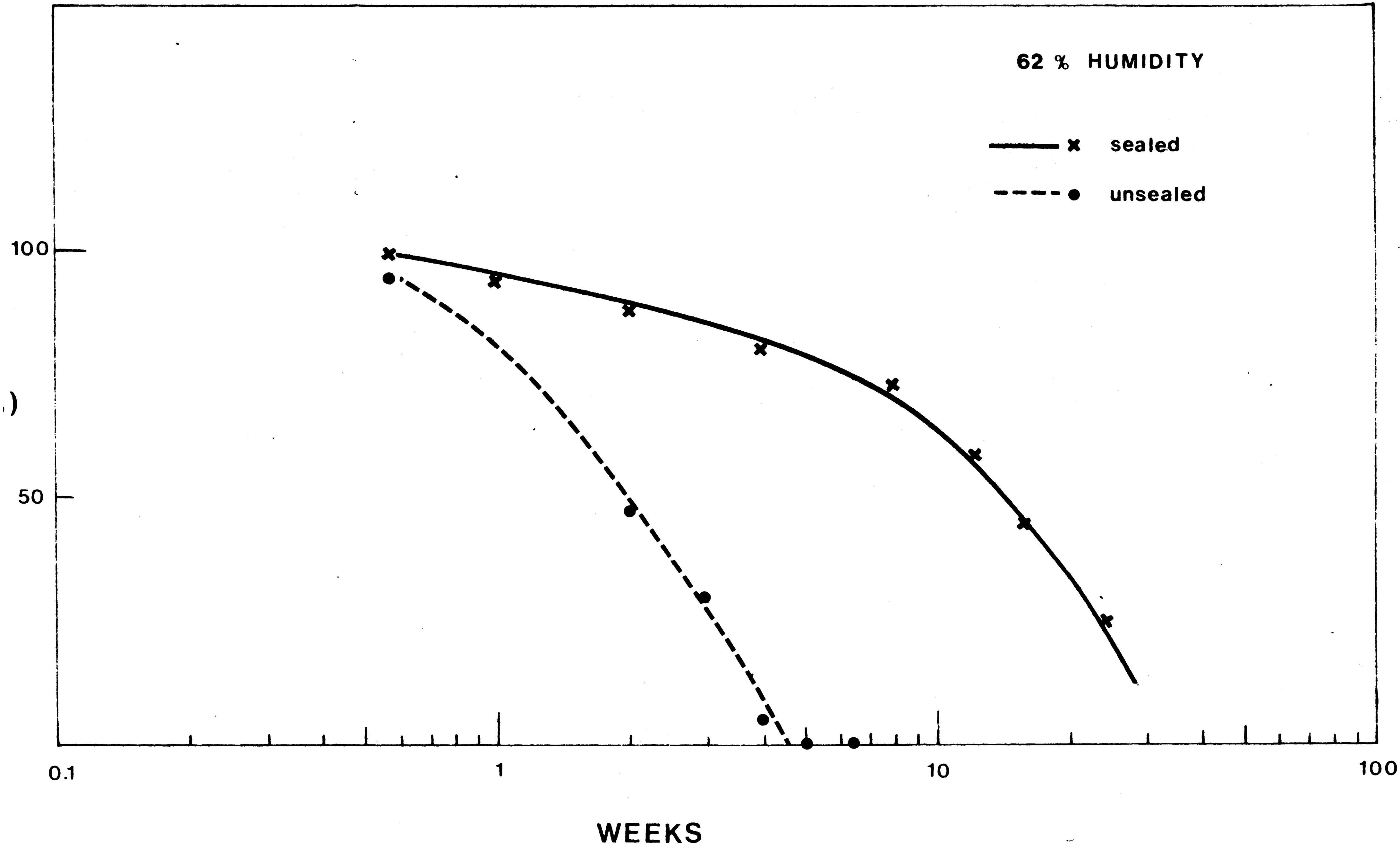
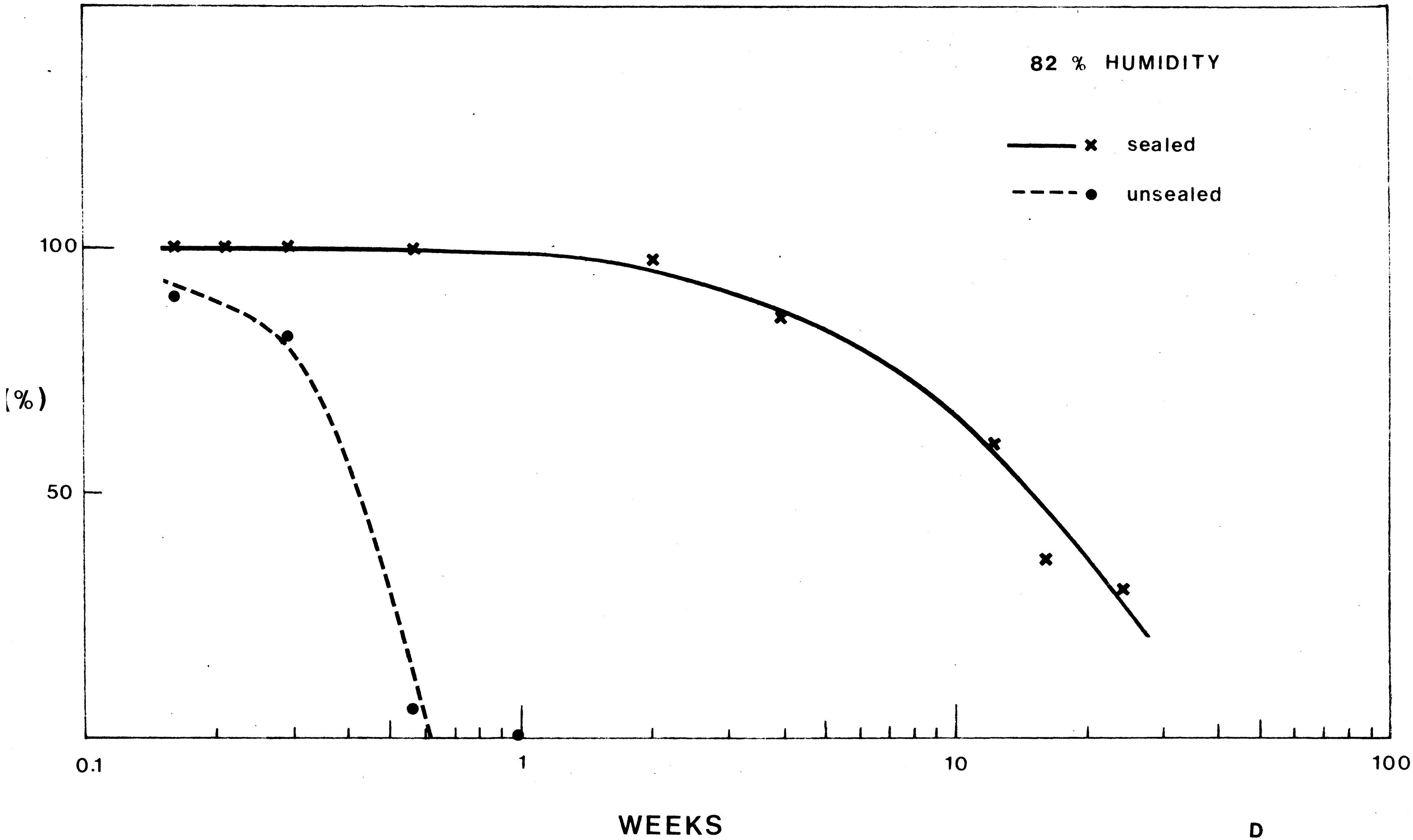


FIG.6



D

FIG. 7

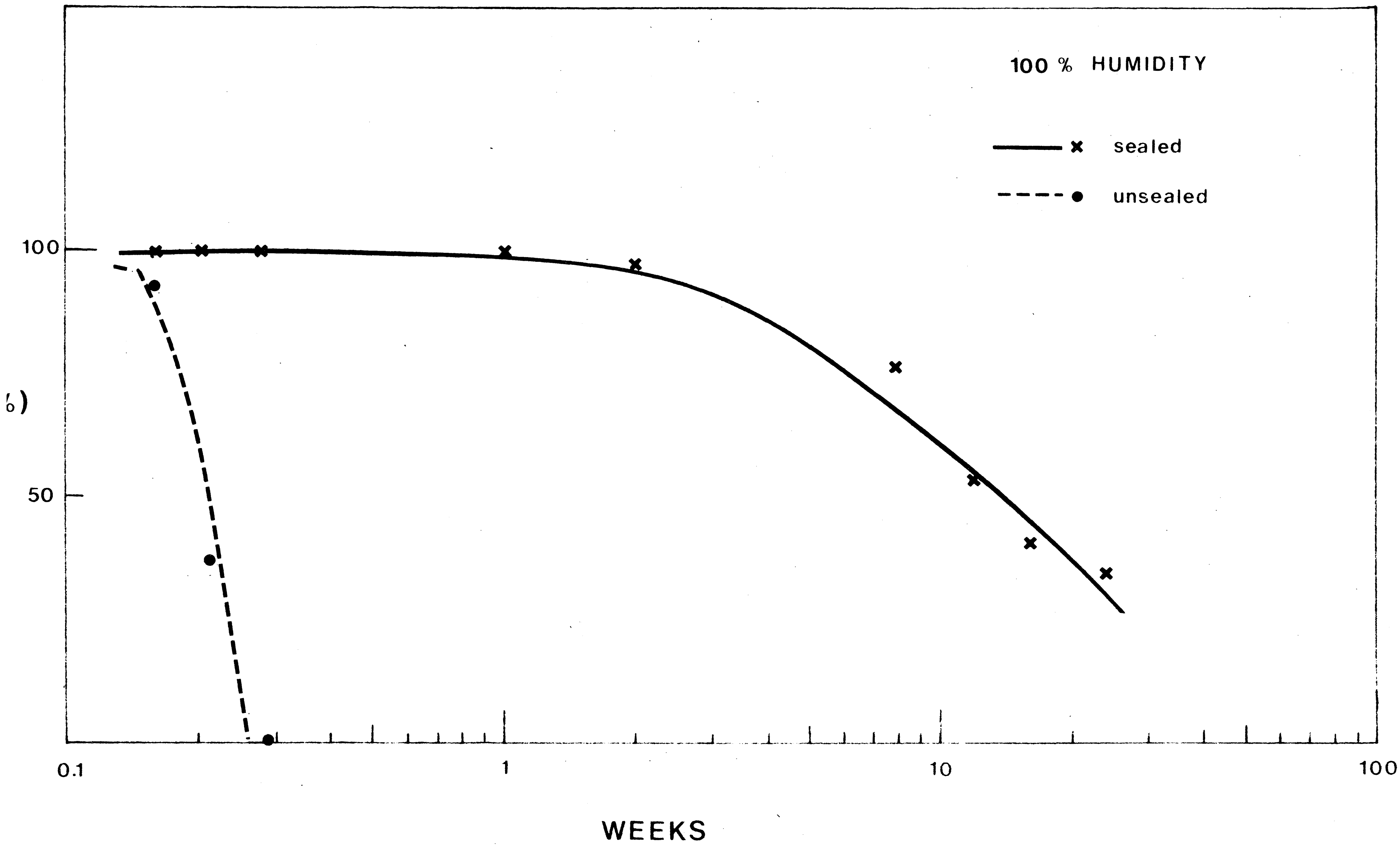


FIG.8

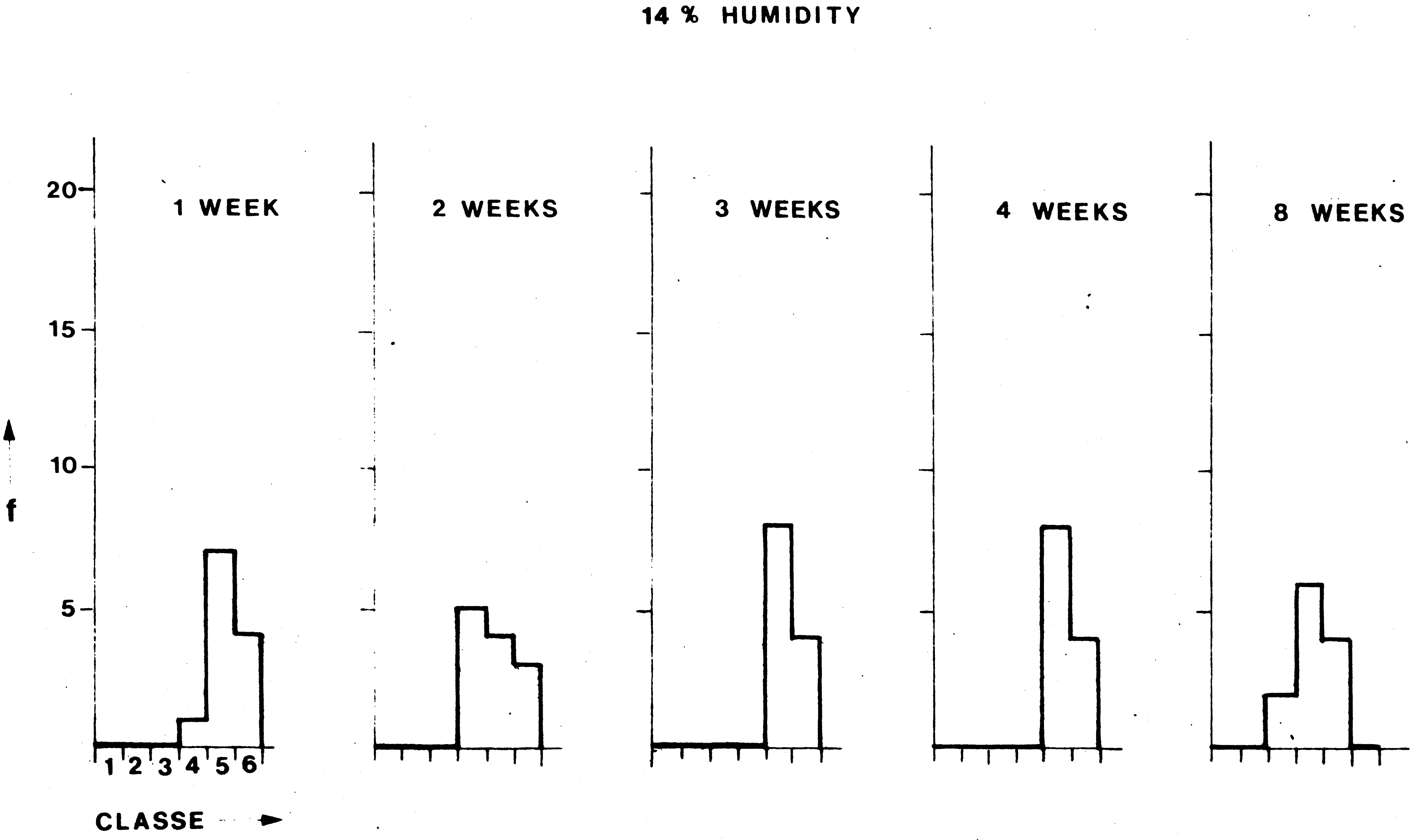

14 % HUMIDITY
20
15
10
5
f
1 WEEK
2 WEEKS
3 WEEKS
4 WEEKS
8 WEEKS
1 2 3 4 5 6
CLASSE

FIG. 9

38 % HUMIDITY

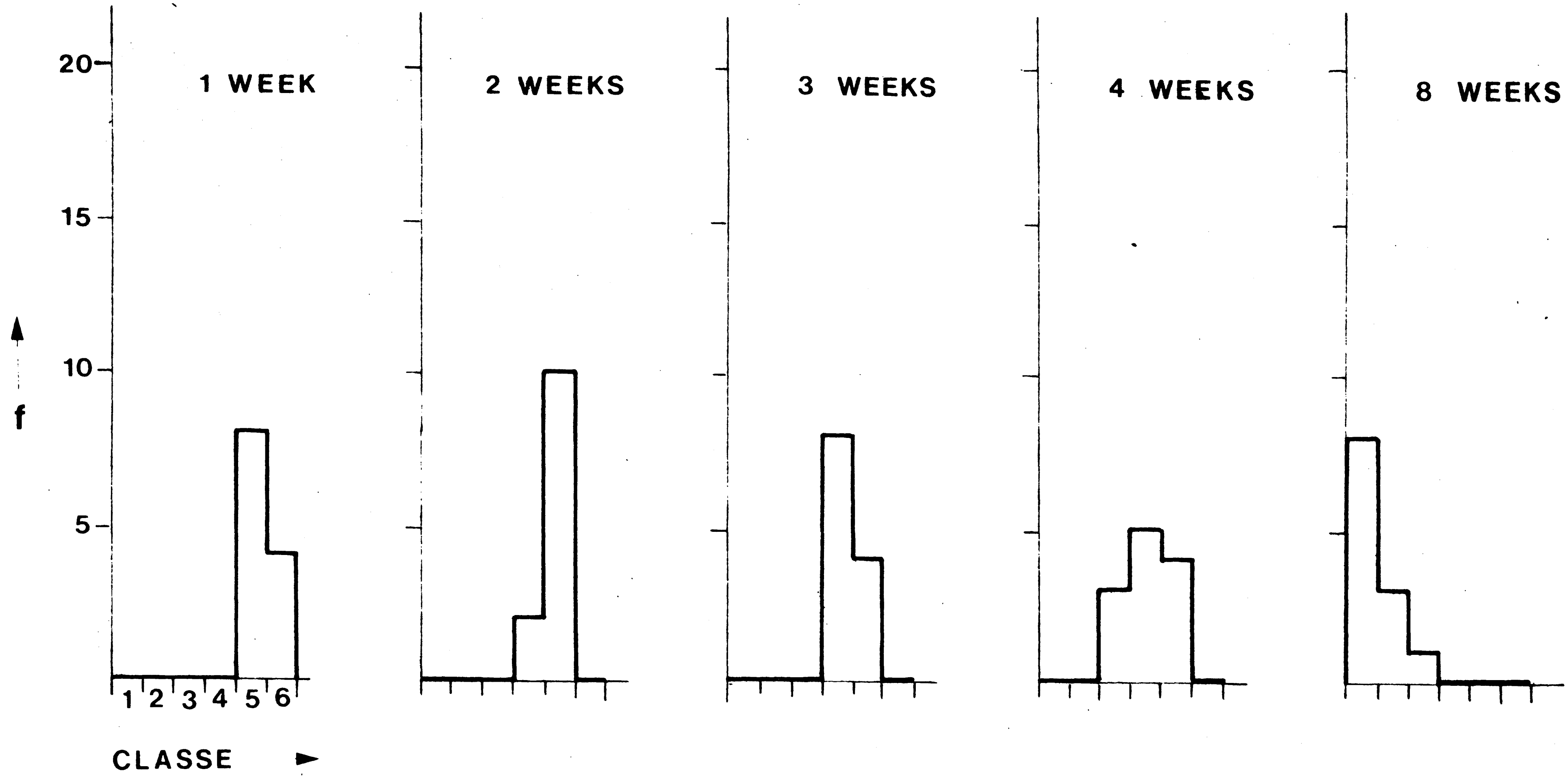


FIG. 10

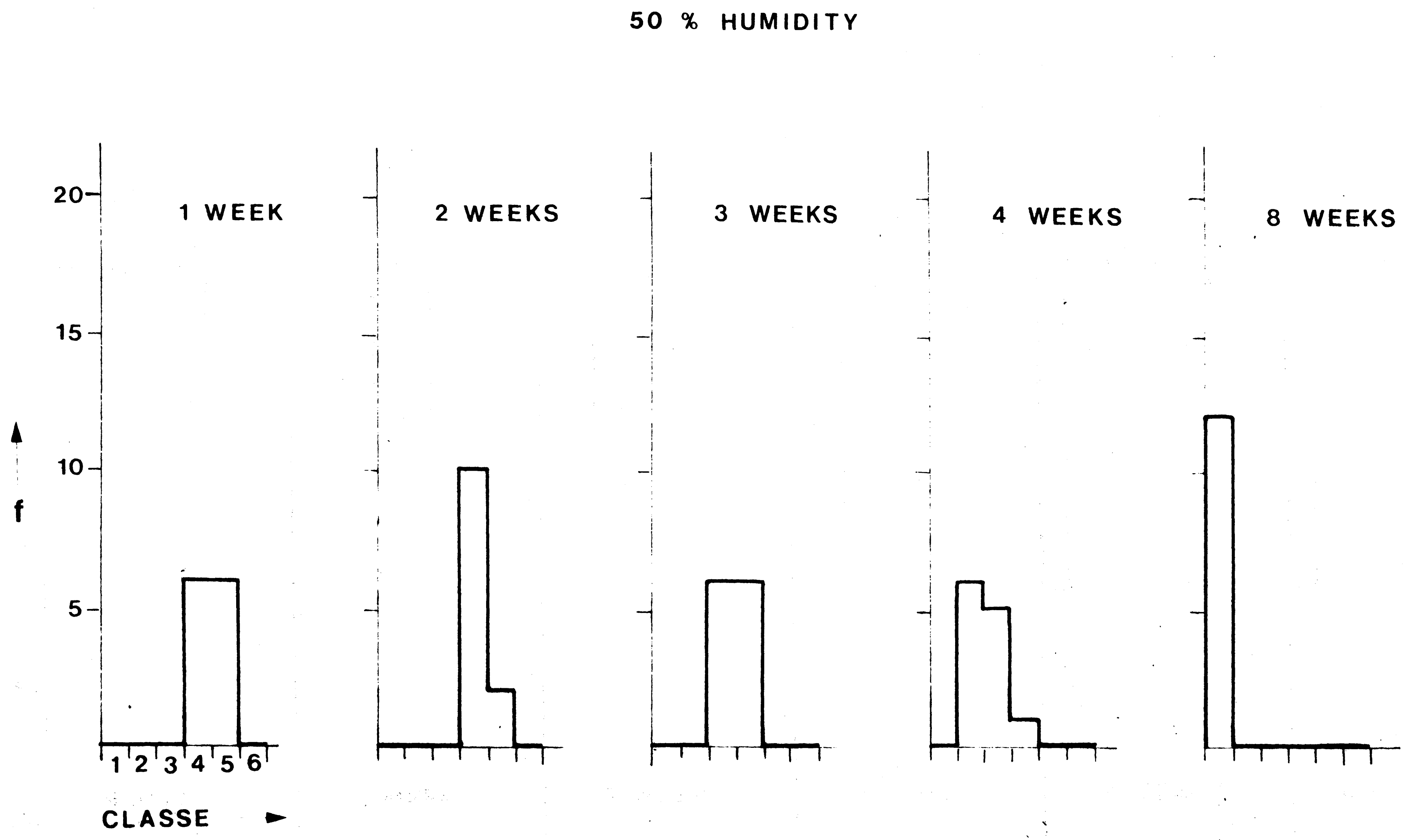

50 % HUMIDITY
20
15
10
5
f
1 WEEK
2 WEEKS
3 WEEKS
4 WEEKS
8 WEEKS
1 2 3 4 5 6
CLASSE

FIG.11

62% HUMIDITY

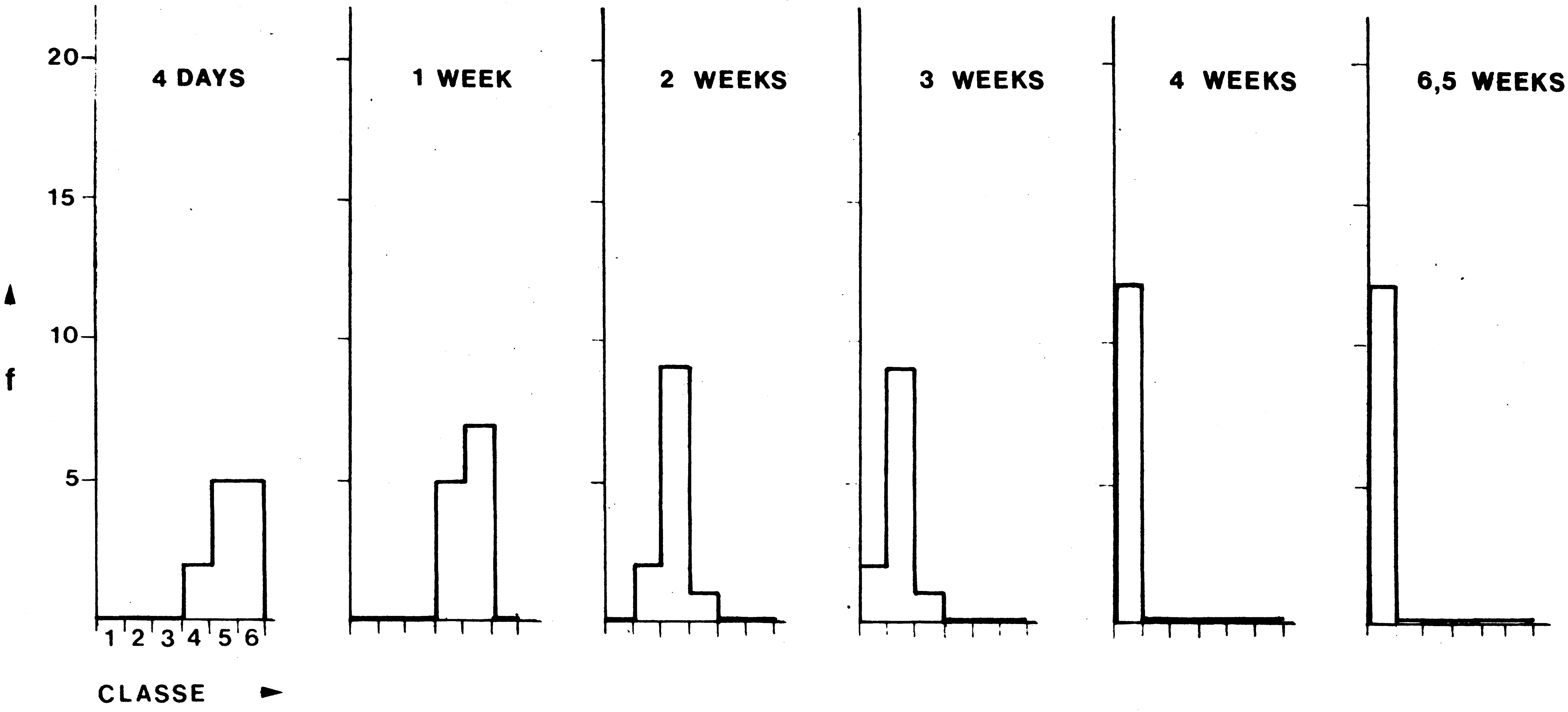


FIG. 12

82 % HUMIDITY

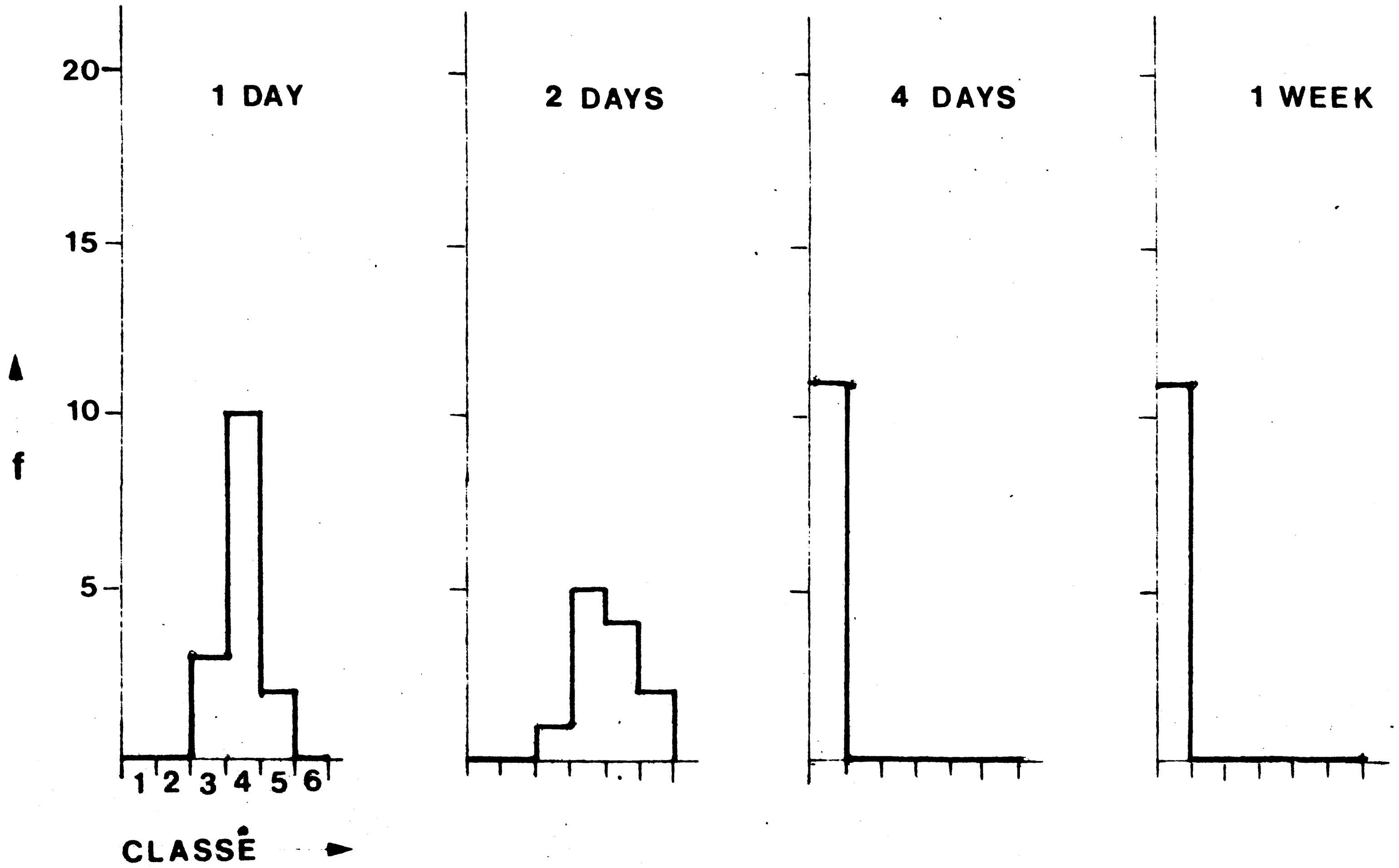


FIG. 13

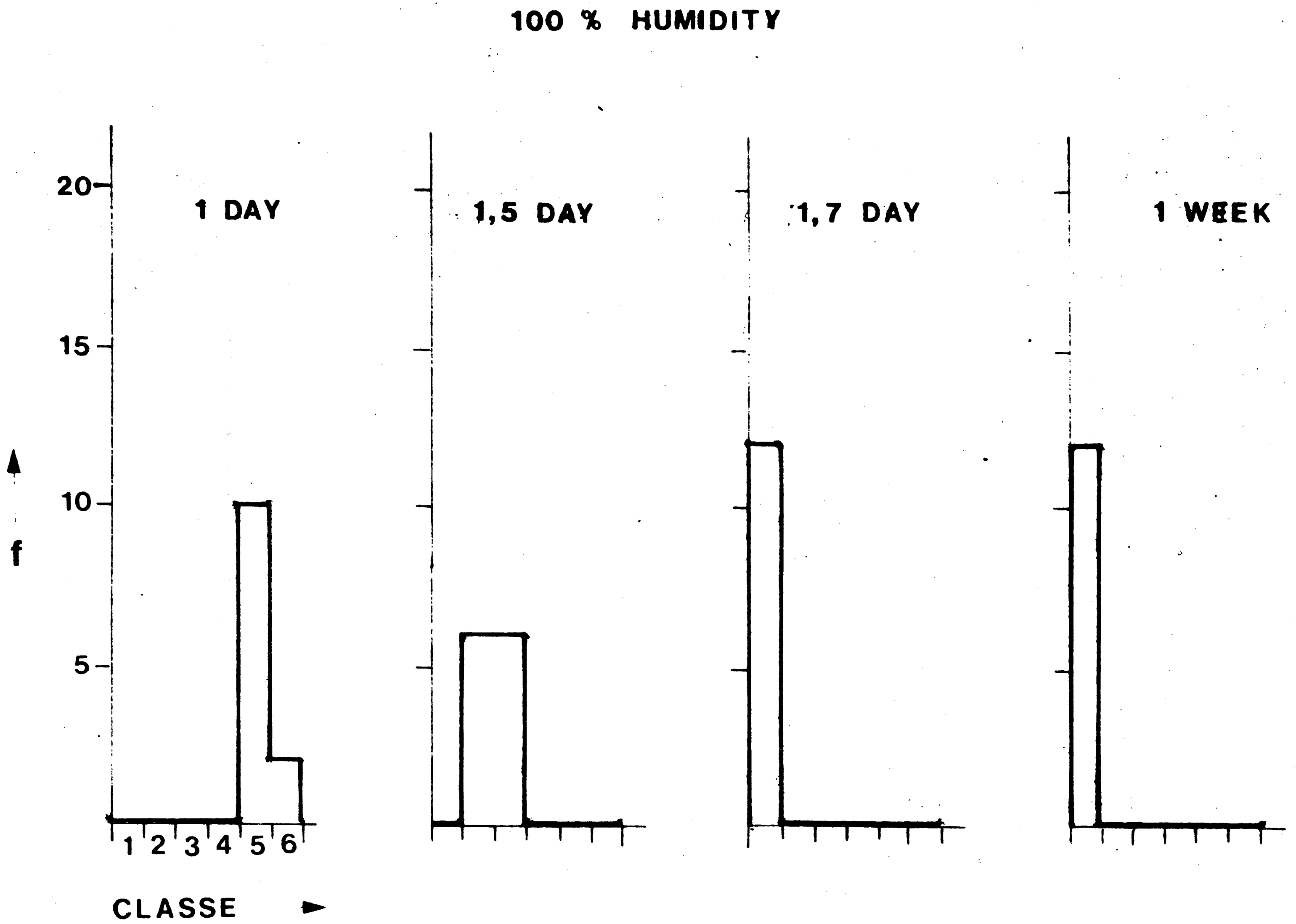

100 % HUMIDITY
1 DAY
1,5 DAY
1,7 DAY
1 WEEK
20
15
10
5
f
1 2 3 4 5 6
CLASSE

FIG. 14

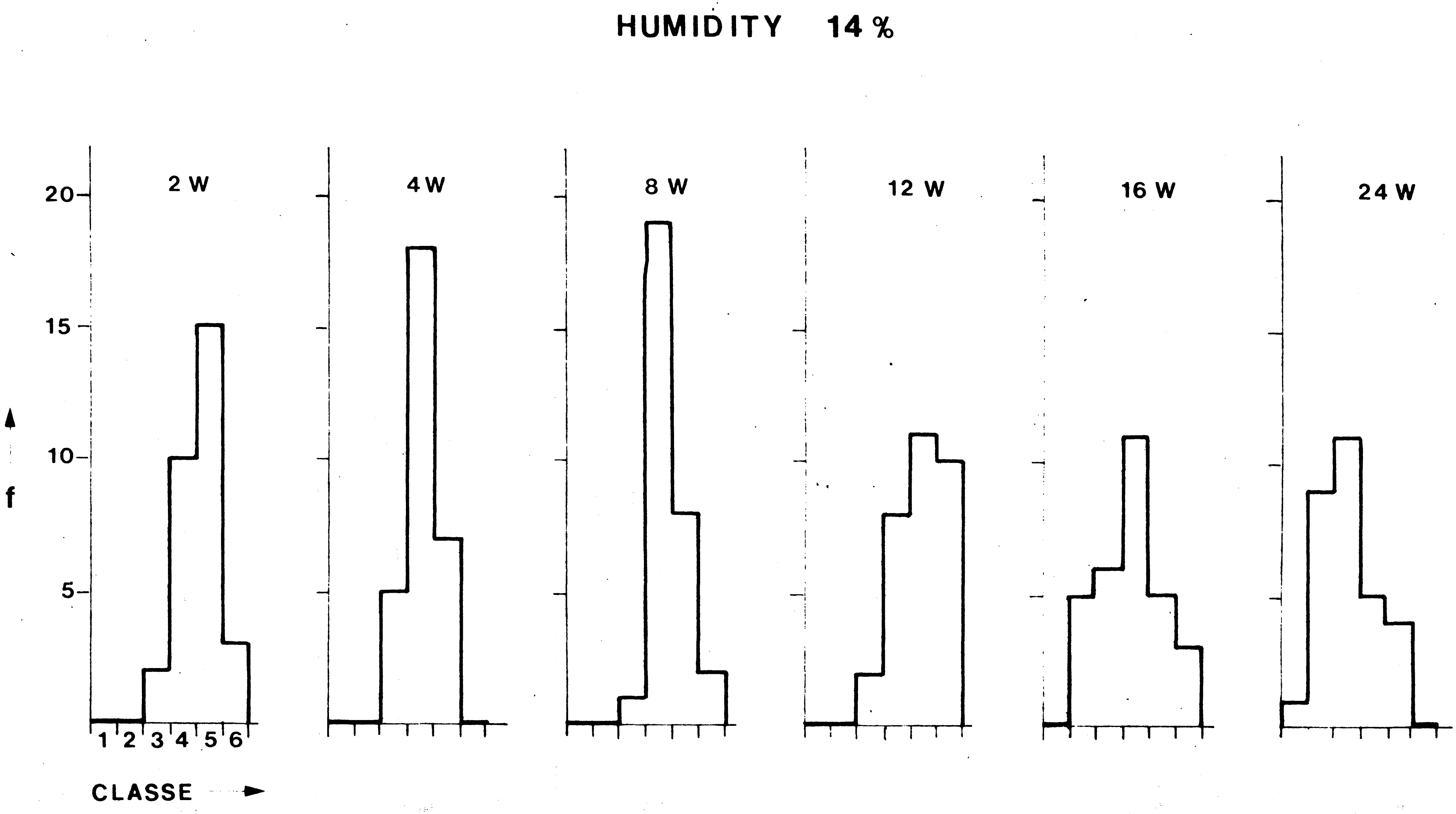


FIG. 15

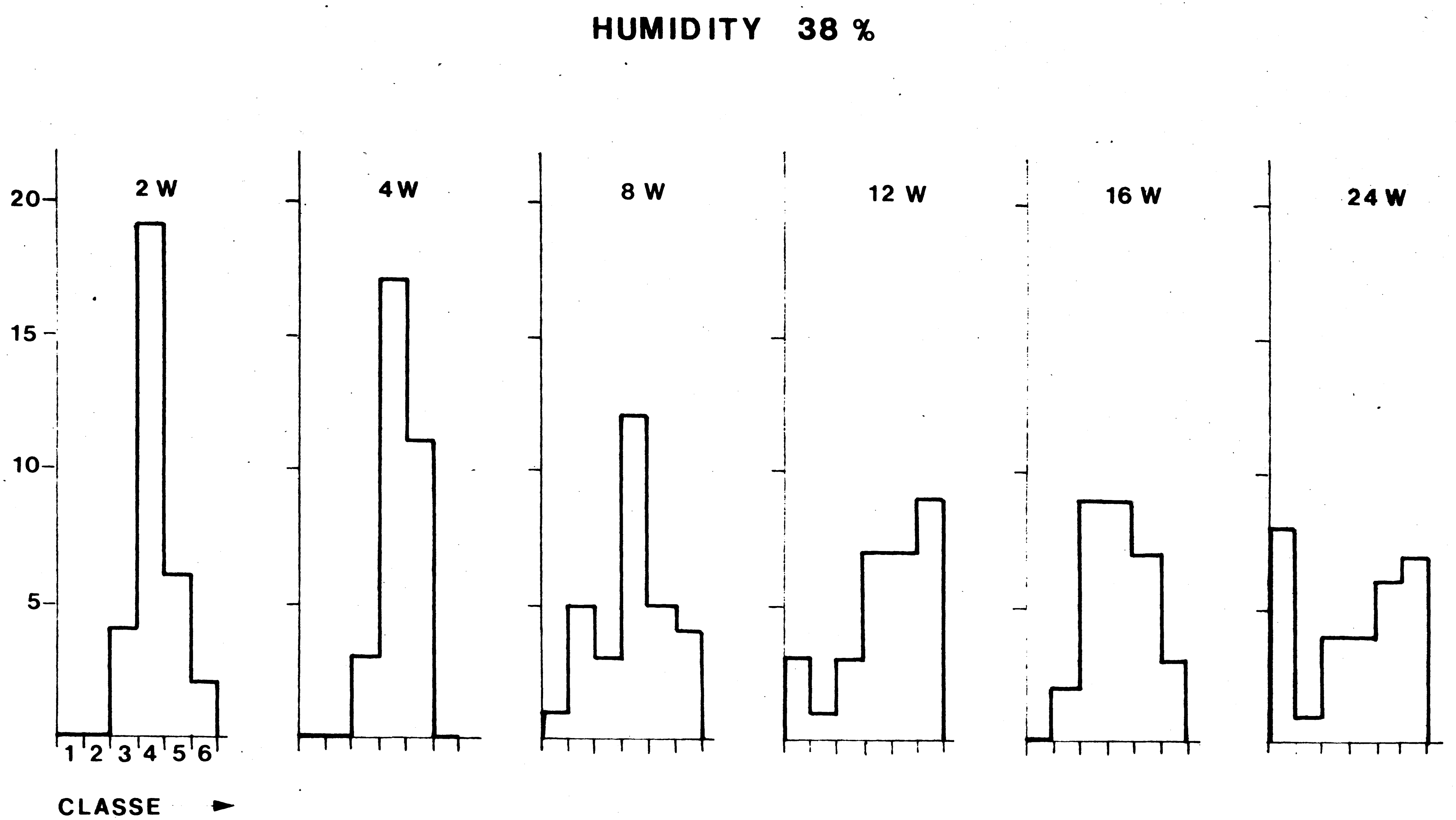


FIG.16

HUMIDITY 50 %

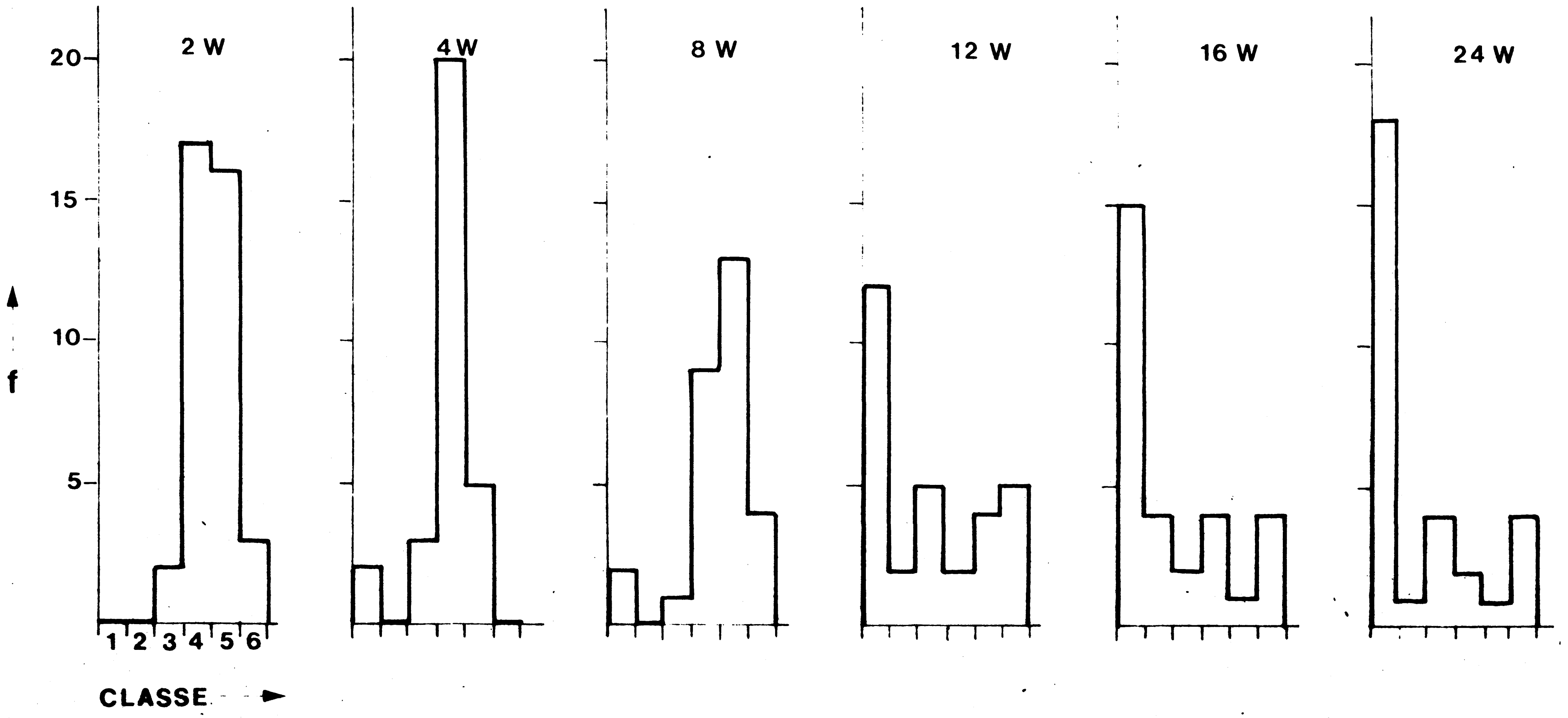


FIG. 17

HUMIDITY 62 %

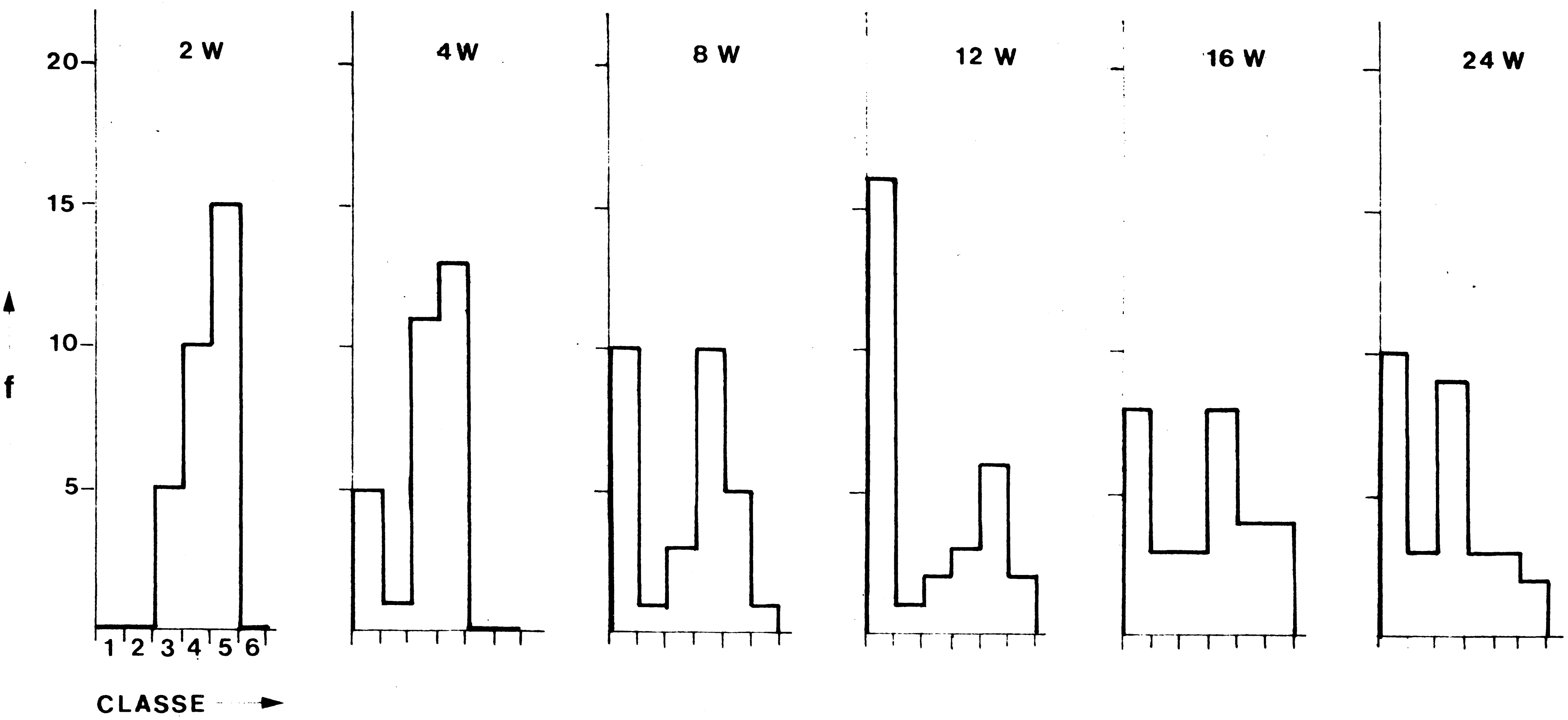


FIG.18

HUMIDITY 82 %

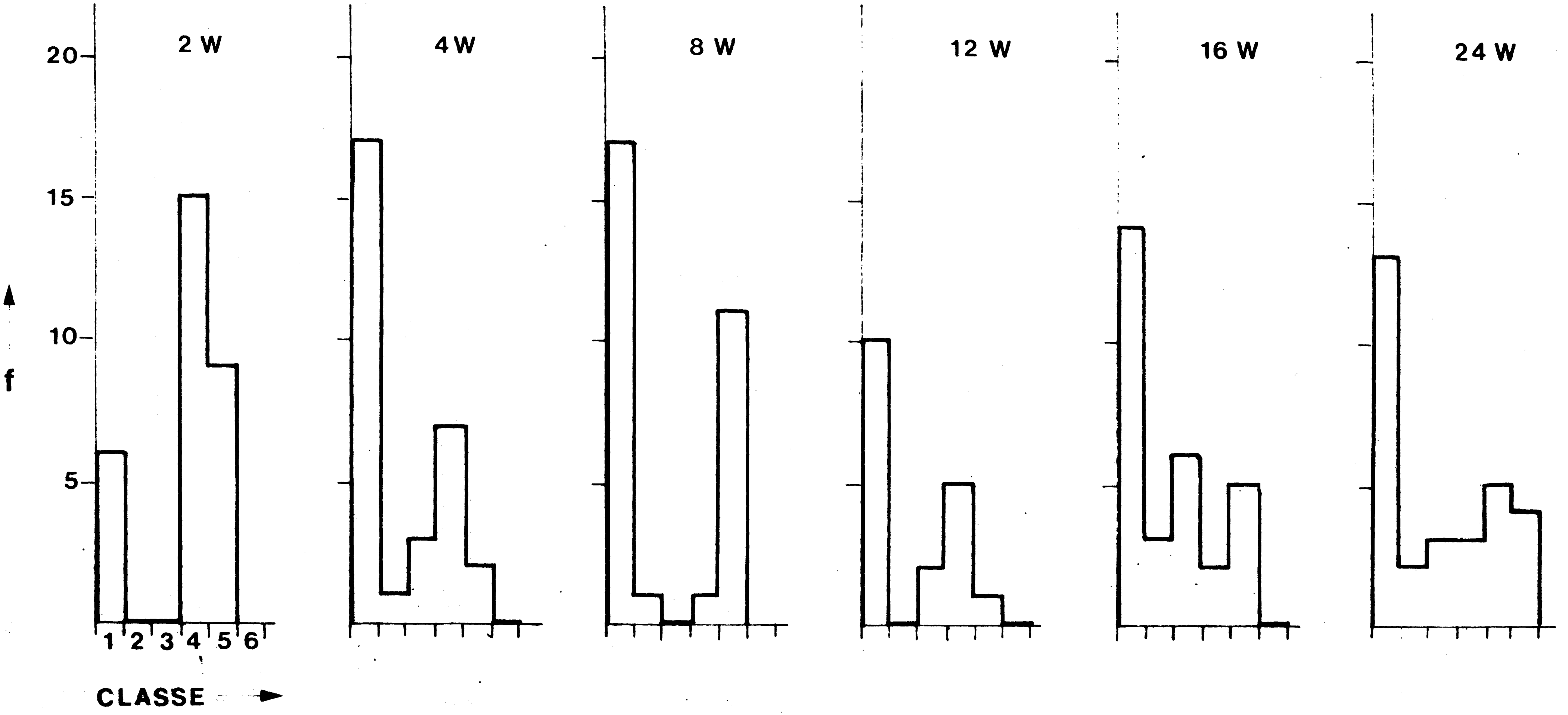


FIG. 19

HUMIDITY 100%

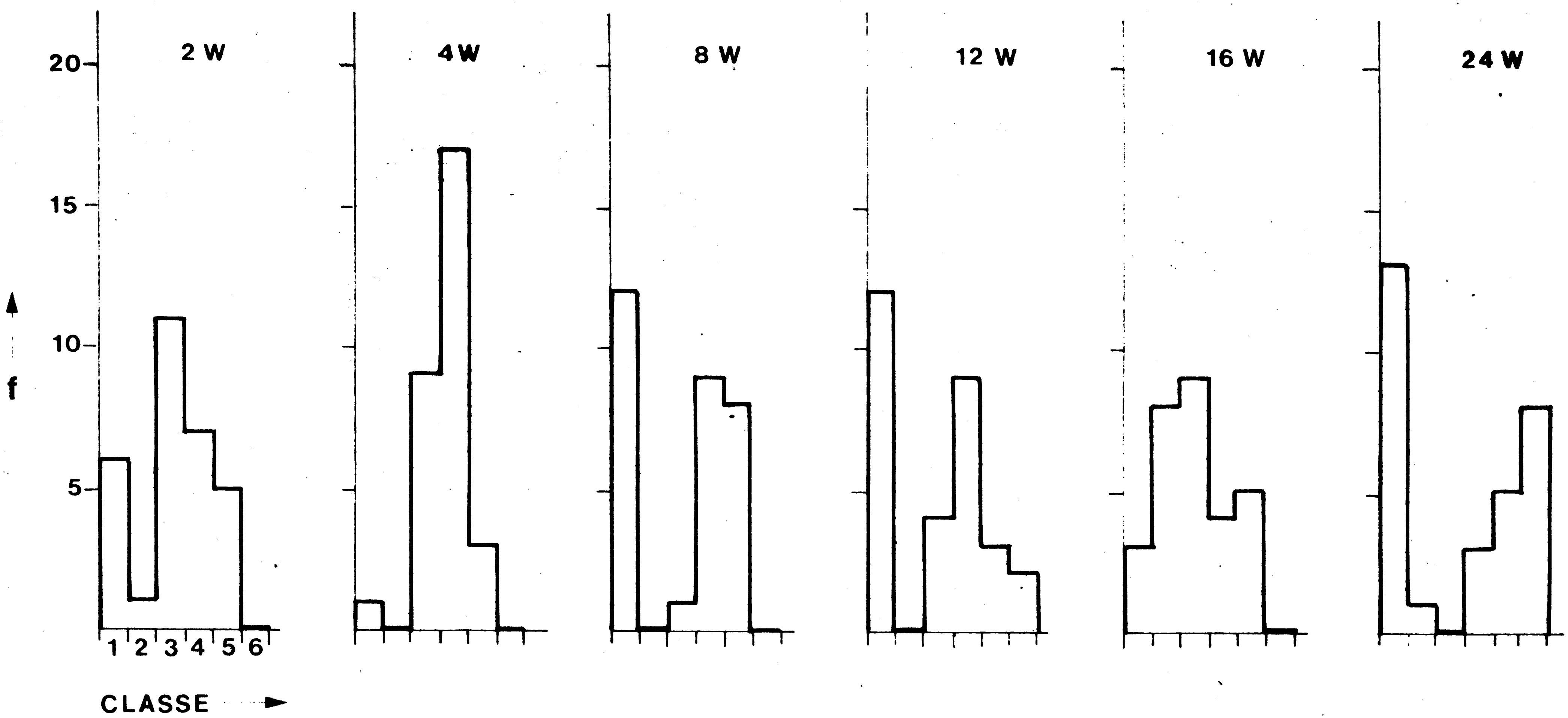


FIG. 20

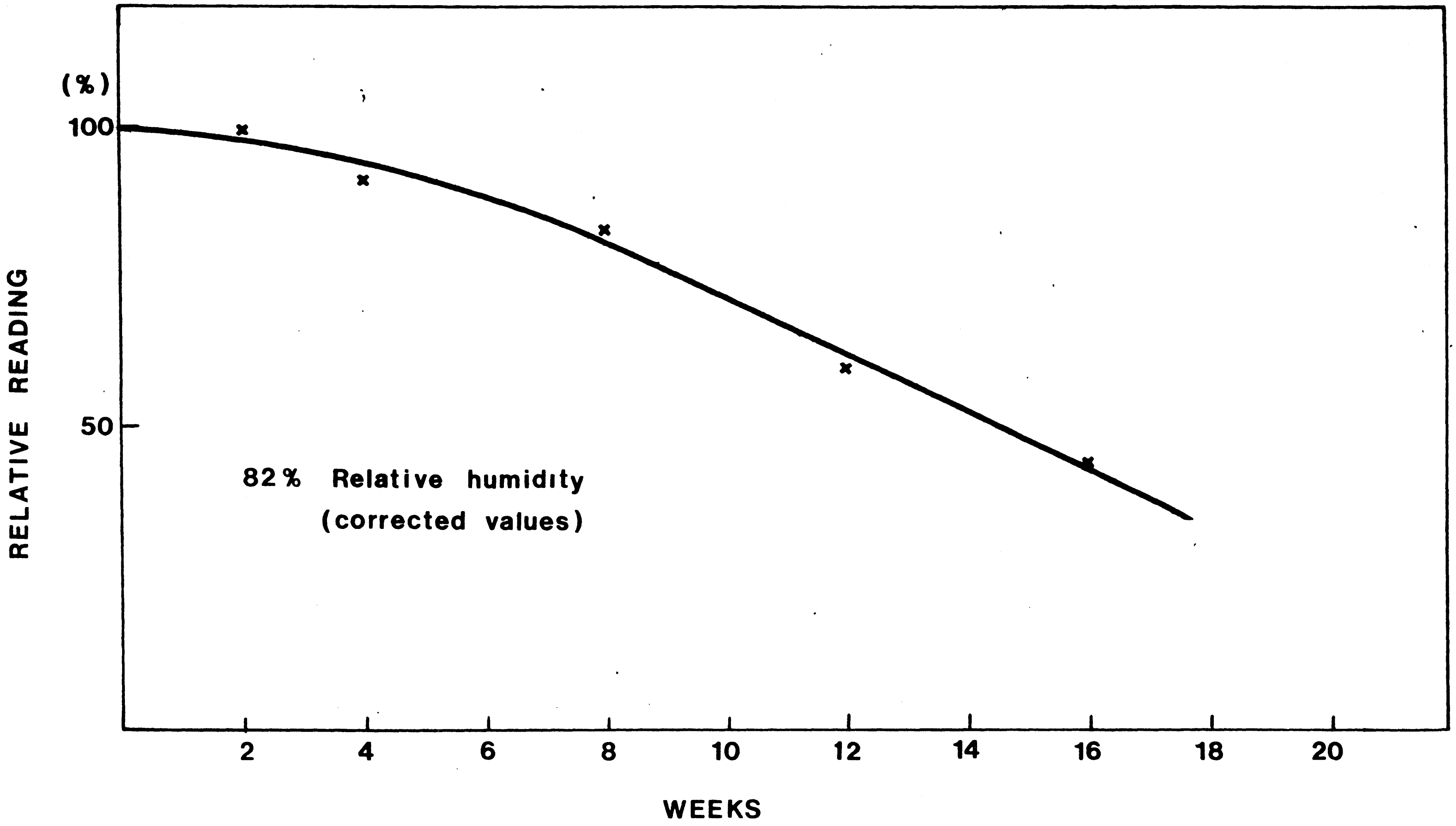

(%)
100
50
RELATIVE READING
82% Relative humidity
(corrected values)
2
4
6
8
10
12
14
16
18
20
WEEKS

FIG.21