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# THE CONCEPT OF MOISTURE REGIMES AND ITS APPLICATION IN IRRIGATION RESEARCH

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## INTRODUCTION

FIELD crops showing moisture stress are not an unfamiliar sight, even in the 'Rainy' climate of Ceylon. Wikramanayake (1958) has shown that in Peradeniya a moisture deficient period (drought) of 10 days or less could be expected four years out of ten during the main vegetable growing season. Dry spells during critical periods of growth, always result in reduced yields. In the 'dry zone' the dry period from June to September seriously limits crop production during the Yala. These hazards could generally be avoided, if supplementary irrigation was available at the right time and in the right amounts. Till very recently, methods of arriving at irrigation requirements for crop plants, were largely empirical. Fortunately, these are now being replaced by more reliable techniques, which allow a greater degree of irrigation control and which offer definable and reproducible methods of evaluating the soil moisture relations of a crop.

Experimental evidence with a number of crops has shown that a soil maintained at or near field capacity is conducive to optimal plant growth. Under these conditions the soil holds the maximum amount of water it can hold against the forces of gravity. Once a soil begins to dry, it becomes necessary to assess the stage at which lack of moisture becomes limiting to plant growth. In recent years Penman (1953) has provided a fairly satisfactory and workable solution to the problem of assessment of the rate of moisture loss, basing his calculations on the assumption that simple meteorological data can be related to the water lost by a green cover. Thus the moisture deficit in a soil at any particular time can be worked out and irrigation applied.

## CONCEPT OF MOISTURE REGIMES

HUDSON et al (1955) advanced an equally useful concept when they stated that in order to find the critical stage in the drying cycle, which would be limiting to plant growth, one approach was to grow the plants in a series of different, definable and reproducible moisture regimes in each of which the soil moisture is allowed to fluctuate only between two pre-determined conditions, one being field capacity and the other a measurable stage in the drying cycle. Moisture regimes are chosen based on pre-determined tensions beyond each of which the soil is never allowed to dry at any time, moisture tensions being particularly useful, because they are related to the forces that must be overcome by a plant when it takes up water. At these pre-determined tensions the soil is irrigated to bring it back to field capacity and the overall effect of the treatments is then assessed on the basis of their effect on growth and yield.

## EXPERIMENTAL PROCEDURE

IN an attempt to estimate the soil moisture deficits that could be allowed to develop without serious loss of yields in grassland subjected to frequent defoliations, Appadurai (1961) in an experiment conducted at Wye in England, applied the concept of moisture regimes to a perennial rye grass/white clover pasture subjected to two intensities and two frequencies of cutting.

## TREATMENTS

THE following treatments were included in the experiment:—

### (A) *Cultural* :

#### Heights of cutting:

Close cut—cut each time to 1" above ground level.

Lax cut—cut each time to 2½-3" above ground level.

#### Stage of growth at cutting:

Grazing stage—cut each time when approximately 8" high (leafy).

Silage stage—cut each time when approximately 14" high (long, leafy to early flower).

(B) *Irrigation:*

Three soil moisture regimes were imposed as follows:—

- (A) Wet—Maintained at or near field capacity by watering every time the soil moisture tension reached 10 cm. Hg.
- (B) Medium—Restored to field capacity every time the soil moisture tension reached 50 cm. Hg.
- (C) Dry—Restored to field capacity once in the middle of the growing season.

The A and B soil moisture regimes were definable and reproducible. Since a suitable dry regime could not be imposed within the scale of the tensiometer, an arbitrary C regime was included.

The twelve treatment combinations were replicated 3 times in a randomized block design and enclosed in a Dutch light structure erected over the experimental area, in order to prevent any rain falling on the soil surface, and in order to facilitate the maintenance of definable and reproducible moisture regimes. Each plot measured a sq. yard.

*Requirements for the maintenance of specific moisture regimes.*

The maintenance of a specific moisture regime requires:—

- (1) A satisfactory method of assessing soil moisture tension so that the soil is not allowed to dry beyond the pre-determined condition.
- (2) A method of calculating the moisture deficit in the soil at the pre-determined tensions.
- (3) The application of the correct amount of water to re-wet the soil to field capacity.
- (4) A suitable method of measuring the amount of water applied.

In order to satisfy the first condition "Key tensiometers" (Galenkamp's growers model) were installed in each of the plots of one replicate and buried at a depth of a foot. Moisture tensions were recorded daily and every time the tensiometers registered the pre-determined tensions, all plots in that regime were irrigated back to field capacity, with the calculated amounts of water.

The second requirement was satisfied by plotting the curve relating soil moisture tension to soil moisture percentage (wt./wt.) for the soil of the experimental area. Permanent wilting percentage was

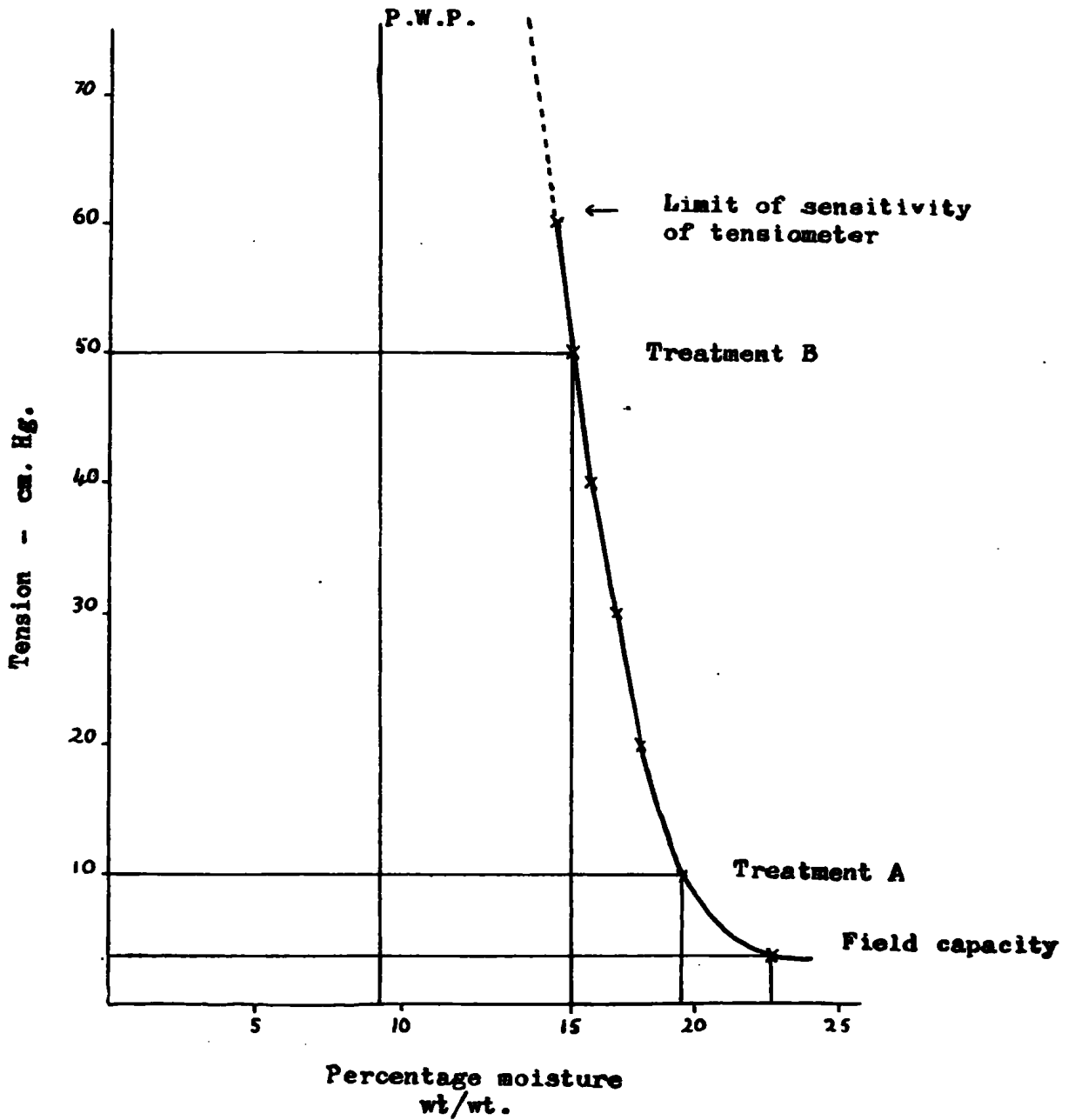


Fig. 1—Soil moisture curve.

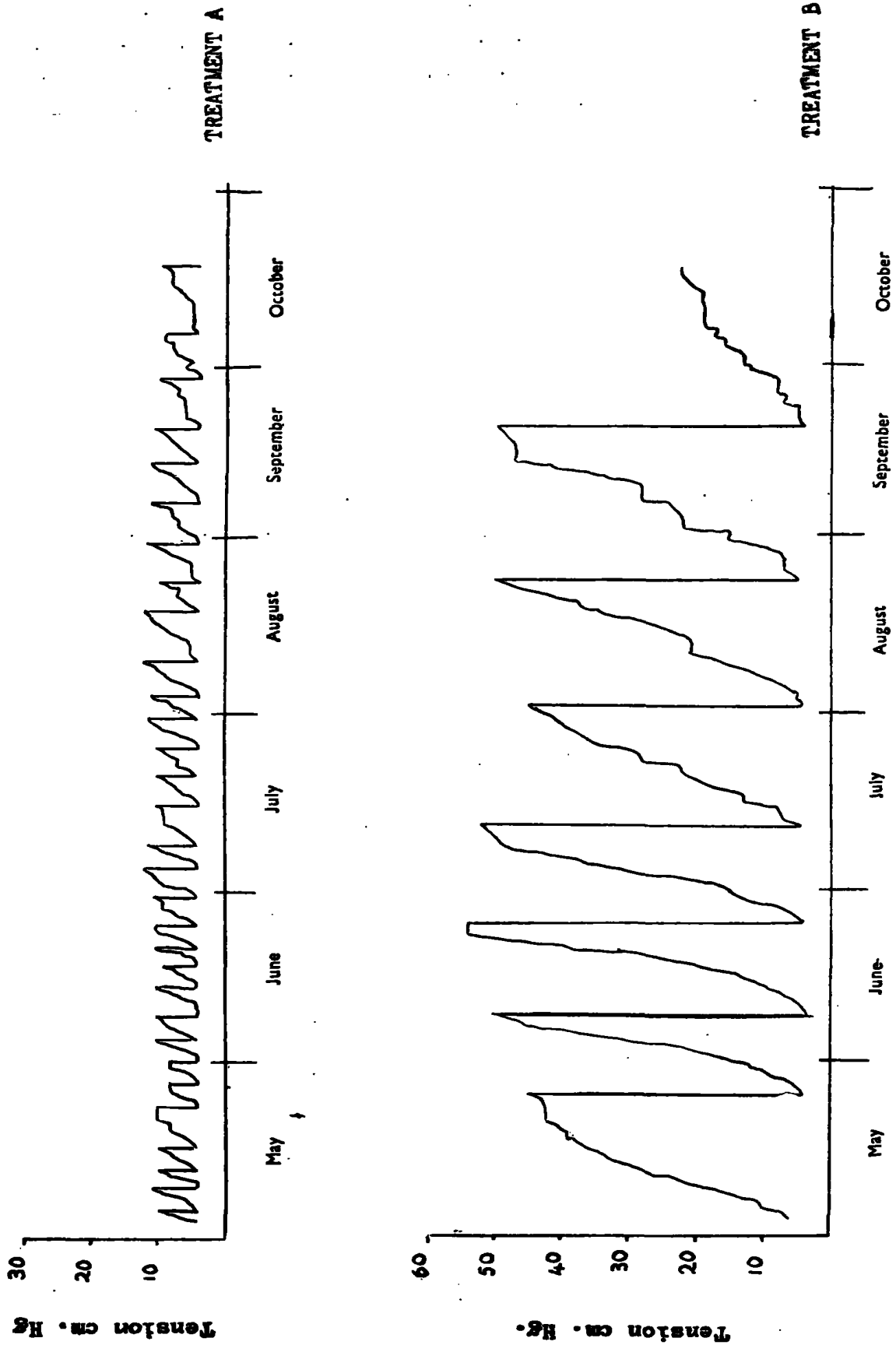


Fig. 2—Soil moisture tensions recorded daily at a depth of one foot under two different moisture regimes—1960.

determined by the method of Veihmeyer and Hendrickson (1949). Figure 1 shows the curve relating soil moisture tensions to soil moisture percentages for the soil of the experimental area, which was a deep, well drained chalky loam and was based on the following set of data :—

<i>Tension cm. Hg.</i>				<i>Moisture % (wt./wt.)</i>
4	..	..	..	22.8
10	..	..	..	19.7
20	..	..	..	18.4
30	..	..	..	17.4
40	..	..	..	16.6
50	..	..	..	15.8
60	..	..	..	15.4
P. W. P.	..	..	..	9.2

The third requirement was met by using the formula by North (1959) for converting percentage moisture deficit into inches, which is as follows :—

$$d = \frac{P \times As D}{100}$$

where *d* equals the amount of available water in inches, *P* equals the amount of water held at field capacity minus the amount of water held at permanent wilting on a percentage basis. *As* is the apparent density of the soil, and *D* equals the depth of soil in feet.

On this basis the calculated amounts of water required to bring 2 feet of this soil to field capacity at the pre-determined tensions were:

- (a) When tensions reached 10 cm. Hg.—3.96 gallons/sq. yd.  
(Deficit in inches=0.4464 per foot of soil).
- (b) When tensions reached 50 cm. Hg.—9.00 gallons/sq. yd.  
(Deficit in inches= 1.008 per food of soil).
- (c) Deficits for the C regime were calculated by gravimetric determination.

The fourth requirement was met by the use of a calibrated water flow meter. All plots were brought to field capacity at the commencement of the experiment. Subsequent irrigations were determined by treatments.

## EXPERIMENTAL RESULTS

MEAN total dry matter yields of mixed herbage, for two years of the experiment (1959-1960) are shown in Table 1, together with the relevant irrigation data. Figure 2 shows the soil moisture tensions recorded daily throughout the season under the A and B moisture regimes during 1960, the vertical lines representing the frequency of irrigation. Table 2 shows the analysis of variance of total dry matter yields of mixed herbage for the two years.

## DISCUSSION

DURING both years there were clear responses to irrigation, but the water needs of the sward seemed to be related to the defoliation treatment imposed. The moisture regimes caused significant differences in dry matter yields, the highest dry matter yields of mixed herbage being obtained with a plentiful water supply. Dry matter yields of mixed herbage under the B and C moisture regimes were 91% and 70% respectively in 1959, and 76% and 54% respectively in 1960 of the yields under the A regime. The highly significant interaction between the type of cut (heights of cutting) and moisture regimes indicated that although close cutting resulted on average in significantly higher yields than lax cutting, yield differences between the two were modified by the moisture regimes imposed. It is clear that re-growth was progressively reduced by close cutting in the treatments in which the moisture level was allowed to fall much below field capacity. These results are in close agreement with the findings of Jantii and Kramer (1956). On the other hand as far as lax defoliation is concerned, the extra yield in terms of both fresh and dry weights obtained under the A regime were obtained at the cost of much more water applied per unit weight of mixed herbage than was the case under the B regime. At the same time treatment B, in which moisture deficits of 1" were allowed to develop between each watering, was evidence of an economy in water use when a lax defoliation was imposed, but restricted the re-growth of swards that were closely defoliated. Low and Armitage (1959) after defoliating swards to 1—2 inches at the grazing stage found that a deficit of 2 inches was clearly limiting to growth.

## CONCLUSIONS

THE techniques described above, which were applied to the study of irrigation requirements in grassland, can be profitably used to study the soil moisture relations of any crop, provided some method of preventing rain falling on the soil surface can be found. In experimental plots and in the green house this should be easy, and the results obtained can then be applied under field conditions. In any case the techniques described enable a greater degree of irrigation control and can be used to gain information not only on how much water to apply, but also when to apply this water in relation to the stage of growth of any crop. Finally, they enable one to determine the latest stage in the drying cycle at which water should be applied before lack of moisture becomes limiting to plant growth.

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TABLE 1.—Mean total dry matter yields of mixed herbage

1959

Moisture Treatment	Tension at which water applied cm.Hg.	Irrigation Data			Mean total yield 100 lb. d.m/acre				
		No. of times water applied	Total amount applied per plot (gallons)	Total amount applied in inches per acre	Grazing Stage		Silage Stage		Mean
					Lax	Close	Lax	Close	
A (wet) ..	10	39	156	34.6	83.3	118.1	84.4	118.7	101.1
B (medium)	50	9	81	18.0	85.2	91.4	85.1	108.0	92.4
C (dry) ..		1	36	8.0	69.7	79.6	71.2	64.3	71.2
				Mean	79.4	96.3	80.2	97.0	

S.E. = ± 3.41

1960

Moisture Treatment	Tension at which water applied cm.Hg.	Irrigation Data			Mean total yield 100 lb.d.m/acre				
		No. of times water applied	Total amount applied per plot (gallons)	Total amount applied in inches per acre	Grazing Stage		Silage Stage		Mean
					Lax	Close	Lax	Close	
A (wet) ..	10	30	120	26.6	100.0	120.6	109.6	136.7	116.7
B (medium)	50	7	63	14.0	81.9	83.7	85.2	102.4	88.3
C (dry) ..		1	15	3.3	58.1	62.0	68.7	64.5	63.3
				Mean	80.0	88.7	87.8	101.2	

S.E. = ± 2.40

TABLE 2.—Analysis of variance of Total dry matter yields of mixed herbage 1959, 1960

Source of Variation	d.f.	Mean Squares	
		1959	1960
Blocks .. ..	2	6769.19 <sup>ns</sup>	30917.53 <sup>**</sup>
Treatments .. ..	11	85615.09 <sup>***</sup>	162624.99 <sup>***</sup>
Grazing vs. silage ..	1	406.69 <sup>ns</sup>	81130.03 <sup>***</sup>
Lax vs. close ..	1	225783.36 <sup>***</sup>	96824.70 <sup>***</sup>
Moisture regimes ..	2	250849.36 <sup>***</sup>	753014.69 <sup>***</sup>
Stage vs. type ..	1	9.96 <sup>ns</sup>	4160.25 <sup>ns</sup>
Stage vs. moisture ..	2	15196.94 <sup>ns</sup>	2822.18 <sup>ns</sup>
Type vs. moisture ..	2	73247.01 <sup>**</sup>	38332.99 <sup>**</sup>
Type × state × moisture ..	2	18489.68 <sup>ns</sup>	9210.13 <sup>ns</sup>
Error .. ..	22	9256.31	4572.95
Total .. ..	35		

\*\*\*Significant at the 0.1% level.

\*\*Significant at the 1% level.