

Drought incidence in relation to rainfed rice

W. S. ALLES

*Research Officer, Central Agricultural Research
Institute, Peradeniya, Ceylon*

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INTRODUCTION

DURING the active growth stages of a plant, a high state of turgidity is necessary in the tissues for their normal growth. The turgidity which exists in a field crop at a particular instant of time is a function of several variables, namely the availability of moisture in the root zone, the evaporative demand of the shoot environment and any controlling influences which may exist within the plant itself. But in general, if the soil is drier than pF 4.2, plants would be subjected to moisture stress and consequently growth activity reduced, unless the atmospheric humidity is exceedingly high. The present study is an attempt to use available information of meteorological and soil conditions, to estimate the number of days on which certain selected root zones have been drier than pF 4.2. Such days are designated as Agricultural Drought Days.

There is no published work on drought incidence in Ceylon which takes account of soil moisture. Drought defined in terms of rainfall, alone is considered in meteorological records and this information is published in the annual reports of the Colombo observatory. Drought in an agricultural sense does not begin when rain ceases, but rather when soil moisture is diminished so that plant roots can no longer absorb water from the soil rapidly enough to replace that lost by the shoot to the atmosphere. This concept has been adopted and widely used in the work of Thorntwaite (1955), Penman (1961), Veihmeyer (1956), Veihmeyer and Hendriksen (1955), Zahner (1956), Van Bavel (1953), and others. The work of Van Bavel and Verlinden (1956), is particularly useful as it provides a means of estimating drought incidence from meteorological records, of rainfall and

evaporation, and the moisture holding capacity of soil. The computations are however subject to the following assumptions:—

- (a) moisture above field capacity is rapidly lost as deep percolation or as run-off.
- (b) moisture below wilting percentage is not available to plants ;
- (c) all moisture between field capacity and wilting percentage is equally available through the whole range, and evapotranspiration proceeds at the potential rate down to wilting percentage and when the base amount is exhausted no further evapotranspiration occurs.

Although these assumptions are controversial, nevertheless there is no practical alternative at the present time, for dealing with a long-term past record, and where elaborate computational assistance is not available.

In the present study drought incidence has been calculated for 63 years, and from this information the statistical expectancy of drought conditions has been derived. This information has been combined with available data on the yield and drought conditions prevalent during seven seasons of rainfed rice cultivation at Maha Illupallama to determine the long-term yield.

Drought day information may similarly be used to determine the yield pattern of other crops, as well as their requirement of irrigation, in order to obtain consistently high yields.

PROCEDURE

Drought days have been calculated for Maha Illupallama in respect of three selected root zones, for the period 1905-1968. The selected root zones are specified in terms of the base amount of available soil moisture rather than in terms of depth of soil in order that the drought information would be applicable to all soils in a region. The base amounts of available soil moisture for which drought days have been calculated are one, two and three inches. Available soil moisture is defined as the amount between field capacity and permanent wilting percentage. When these two values and the bulk density of a soil are known, the particular root zone associated with any base amount of available soil moisture can readily be found. Thus for a soil of field capacity 20 per cent, permanent wilting percentage 10 percent and bulk density 100 lb. per cubic foot, a base amount of

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one inch refers to the root zone consisting of the top six inches, and if soil conditions are uniform, a base amount of two inches refers to a foot depth of soil and three inches to $1\frac{1}{2}$ feet of soil.

If the actual moisture percentage of a soil can be determined for a particular date, the subsequent soil moisture conditions depend on the accretions from rainfall and the depletions of water by evapotranspiration losses.

Daily rainfall records were available for Maha Illupallama from January 1905, while June and July 1905, were completely without rain. Hence it could be reasonably assumed that for all selected base amounts of soil moisture, the soil was at permanent wilting percentage on August 1st 1905. This date was therefore taken as the starting point for the computations.

Although daily rainfall measurements exist, measured evapotranspiration values are not available and require to be estimated. Pan evaporation measurements were available for several years. In the present study, the average monthly values of pan evaporation were divided by the days in each month to obtain a value for the daily evaporation in respect of each month. These values have been assumed to be equal to the potential evapotranspiration. Although this is not strictly valid, nevertheless, it is not a disadvantage for the particular use made of the data in relation to rainfed rice. However, in future work it is proposed to use more refined estimates of evapotranspiration in order to make the drought day information more reliable and widely applicable.

RESULTS

During the maha seasons 1962/63 to 1968/69, the rainfed rice crop at the Maha Illupallama Research Station has been grown on the same land under more or less similar conditions, with tillage practices, varieties sown, fertiliser application, weed control methods, pest and disease control, etc. remaining the same. Hence most of the yield variations may be reasonably attributed to variation in the moisture factor. The period of drought susceptibility has been taken as the three-month period October 15—January 15, while the root zone from which moisture is drawn has been taken as the top six to nine inches of soil. In tables I and II are given the drought day incidence during the seven maha seasons considered, while in Figure I and tables III and IV are given the long-term drought day expectancies.

TABLE 1.—Drought Days and Yield in Seven Seasons of Rainfed Rice

Season			Acreage	Yield in Bushels/acre		Total Drought Days
1962/63	..	..	25	..	30	18
1963/64	..	..	24	..	71	8
1964/65	..	..	10	..	8	23
1965/66	..	..	12	..	40	19
1966/67	..	..	20	..	40	19
1967/68	..	..	24	..	25	22
1968/69	..	..	20	..	12	21
Average of seven seasons		..	..	..	32	
(not weighted for acreage)						

TABLE 2.—Number of periods of consecutive drought days of duration equal to or greater than specified below, during the period October 15—January 15

Season			5 Days	7 Days		10 Days	15 Days	
1962/63	..	..	2	..	1	..	Nil	Nil
1963/64	..	..	1	..	Nil	..	Nil	Nil
1964/65	..	..	3	..	2	..	1	Nil
1965/66	..	..	2	..	1	..	1	Nil
1966/67	..	..	2	..	1	..	1	Nil
1967/68	..	..	2	..	1	..	1	Nil
1968/69	..	..	3	..	1	..	Nil	Nil

TABLE 3.—Long-term expectancy in percentage of years, of consecutive drought day periods of duration equal to or greater than specified below, for the period October 15—January 15

Specified Duration in Days		With at least one period		With at least two periods		With at least three periods	
5	..	89	..	64	..	38	
7	..	75	..	38	..	16	
10	..	51	..	11	..	Nil	
15	..	19	..	Nil	..	Nil	

TABLE 4.—Long-term expectancy, in percentage of years, of consecutive drought day periods of duration equal to or greater than specified below, for the period October 15—December 31

Specified Duration in Days		With at least one period		With at least two periods		With at least three periods	
5	..	66	..	30	..	6	
7	..	51	..	15	..	1	
10	..	32	..	4	..	Nil	
15	..	14	..	Nil	..	Nil	

DISCUSSION

In this study rainfed rice yields have been viewed from two aspects of the moisture factor, namely the total number of drought days and the occurrence of drought days on successive days for specified durations.

In the seven seasons of data available, the most favourable season was in 1963/64, while the most unfavourable was in 1964/65.

Tables III and IV and Figure I show that conditions more favourable as well as conditions more unfavourable could be expected to occur in some years. The percentage of such years can be ascertained. In the 1963-64, season when the highest grain yield was obtained, the total drought days was eight and there was one period of five consecutive drought days, but none of seven or more days. In about ten per cent. of the years, conditions would be even more favourable; i.e., without a single period of five consecutive drought days and less than a total of eight days. Therefore yields would exceed 70 bushels/acre in about ten per cent. of the years and possibly average about 80 bushels/acre.

In 1964-65, when the lowest yield was obtained the total drought days was 23 and twelve days occurred consecutively. Fifteen consecutive drought days did not occur in any of the seven seasons of study. But such an event is likely in 19 per cent. of the years, while in 40 per cent. of the years the total drought days would exceed 23. It may be concluded therefore that in about 20 per cent. of the years rice yields would be less than 10 bushels/acre.

Extremely high variability is to be expected in rainfed rice cultivation in Dry Zone locations such as Maha Illupallama. It is not possible to deduce the exact long-term pattern of yield from the available information, but it is clear from the present data that the long-term average yield is unlikely to be higher than the average value of the seven seasons of information. In fact indications are that it may be slightly lower. A figure of 30 bushels/acre is a reasonable tentative value for the long-term average yield of the four month age class varieties that are available.

At these yield levels it is hardly profitable to grow rainfed rice. The cost of cultivation of a rainfed rice crop according to the recommendations of the Maha Illupallama Research Station has been estimated at Rs. 420 per acre. This is equivalent in value to 30

bushels of paddy at Rs. 14 per bushel and thus there is no profit margin. However, at lower levels of management with lower inputs such as under chena conditions, rainfed rice cultivation may be profitable although yields also would be lower.

The adverse effects of drought can be considerably reduced by growing a good 3 1/2 month variety. This is clearly indicated in Table IV. In this case the proportion of seasons without even a five-day consecutive drought period is 35 per cent. as against 10 for the four month varieties, while the proportion of very unfavourable seasons with a 15 day drought period is 14 as against 19 earlier. It should be possible to achieve a long-term yield level of about 50 bushels/acre with a 3 1/2 month variety whose yield potential is similar to that of the existing four month varieties. An intensified research programme in rainfed rice agronomy is therefore a worthwhile venture.

Lastly, the type of land on which rainfed rice has been at Maha Illuppallama deserves mention. The land is a lower member in the Reddish Brown Earth catena and mapped as the Talawa and Manewa soil series. Drainage is described as moderate to poor, and the land slope is about three to four per cent. Broadbased terraces have been constructed on the land but otherwise the natural external drainage is unimpeded. Pondered water does not occur except in isolated patches.

Rainfed rice would grow much better if land is bench terraced to form 'liyaddas' so that pondered water may remain, as in typical irrigated paddy lands with provision to drain off excess water when necessary. Under these conditions the onset of drought during rainless periods may be considerably delayed. The extra cost of bench terracing the lands would be amply justified by the increased yields that would be obtained.

SUMMARY

The concept of a "Drought Day" has been used to study the moisture stress suffered by plants, and the incidence of drought days has been calculated for a period of 63 years, based on the climatological records of Maha Illuppallama. Relevant information from this study has been used to determine the long-term yield of rainfed rice.

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LITERATURE CITED

1. Annual Reports of the Colombo Observatory.
2. PENMAN, H. L., (1961) The Movement and Availability of Soil Water
Soils and Fertilizers, *Comm. Bur. Soil Sci* 19 : 221-225.
3. THORNTWAITE, C. W., (1955). The Water Balance, Drexel Institute of
Technology. Publications in Climatology Vol. II, No. 1. Centerton,
New Jersey.
4. VEIHMEYER, F. J., (1956) Soil Moisture, *Hanbuck der Pflanzenphysio-
logie* 3 : 64-123.
5. VEIHMEYER, F. J. and HENDRIKSEN, A. H., (1955) Does Transpiration
Decrease as Soil Moisture Decreases ? *Trans. Amer. Geoph. Union*
36 : 425-428.
6. VAN BAVEL, C. H. M., (1953) A Drought Criterion and Its Application
in Evaluating Drought Incidence and Hazard *Agron Journ*,
45 : 167-172.
7. VAN BAVEL, C. H. M. and VERLINDEN, F. J., (1956) Agricultural Drought
in North Carolina *Agric. Expt. Sta. Tech. Bul.* No. 122.
8. ZAHNER, R., (1956) Evaluating Summer Water Deficiencies Southern
Forest *Expt. Sta. U. S. D. A. Occasional Paper* No. 150.
9. Reports of the Rainfed Rice Research Section, *Agric. Research Sta.
Mahailuppallama*.

Figure 1—Cumulative frequency diagram of total drought days occurring between October 15-January 15, based on 63 years record.

