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Water Requirements of Crops, with Special Reference to Rice

By

SRI M. B. V NARASINGA RAO,
Paddy Specialist, Coimbatore.

Since all agriculture is dependent on water, it is not surprisng that centres of ancient civilization have all been close to perennial river systems. Later on, people have constructed dams and storage reservoirs. to spread out the water supply from these rivers more uniformly and control the risk of periodical floods and inundations. Tank systems are also similar in their aim and execution. In any system of irrigation however, one has to take into account the quantity of water available and the quantity needed by different crops at different stages of their life cycle.

The present paper is a review of the work done so far in India, on the water requirements of different crops, with special emphasis upon Rice, as it is the most important amongst all our food crops. The material has been culled out from various Annual Reports of different State Departments of Agriculture and Schemes financed by the Indian Council of Agricultural Research (1).

The chief factors influencing loss of water from cropped fields are (1) field evaporation, (2) transpiration by growing plants, (3) seepage losses and (4) the preparatory treatments that the land had undergone, such as flooding etc. These factors are in turn influenced by climatic conditions, the nature of the soil and sub-soil, the depth of ground water table, the length of the irrigation season and the agronomic practices in vogue in the particular tract in question. It is also to be kept in mind that not only do different crops require different amounts of water but that even the same crop needs different amounts of water at different stages of its growth-period.

Amongst the factors that influence water losses, the nature of the soil, the distributing channels and the distance of lead are important, as they determine the "transmission losses" as distinct from loss by evaporation. At Maruteru in the Godavari delta, the daily loss of water due to transpiration was nearly 0·02 inch. At Aduthurai in the Tanjore delta, the loss by seepage amounted to 0-02 to 0·03 inch per day, that from evaporation to another 0·02 to 0·03 inch, while the loss from actual transpiration of the rice crop varied from ·01 to ·06 inch per day in different seasons and years. Thus the aggregate loss of water was nearly 0·1 inch per day.

An estimate of similar "evaporo-transpiration" figures is given below for other crops, as reported by McKenzie Taylor (1) in an investigation on the rise of water table in the Punjab in the Upper Chenab Canal area.

Crop.	Water consumed (evaporo-transpiration in inches)
Millet	8
Maize	9
Cotton	12
Fodder	14
Sugarcane	38
Rice	22
Rice (In Madras)	26 to 29 inches (over a period of 135 days' duration).

It would be clear from these data that rice is a crop that needs large quantities of water, although it can adapt itself to some extent to insufficient water supplies.

Singh and his co-workers in the Banaras University (2) observed that there were three district periods of high water requirement in paddy, the first during the seedling stage extending over a period of 10 days, the second during the pre-flowering stage covering about 25 days and the third during the time when the grains are formed, covering a period of 5 or7 days.

Bihar: Experiments (2) were conducted to find out the growth of rice plants under varied conditions of water supply, viz.,

(1) Paddy soil with standing water
(2) Paddy soil under puddled conditions
(3) Paddy soil under a cracked condition

and it was found that paddy thrived best under puddled conditions. The water requirements of late or long duration varieties were (as would be expected) definitely higher than that of early or medium duration varieties.

It was also observed that the water requirements of drought-resistant and flood-resistant types of paddy were lower than that for ordinary varieties of the same duration group, the drought-resistant types being the lowest in their water requirements.

Both in late and in early varieties there was a gradual rise in water requirements from the early stages upto the flowering stage, the maximum being attained just before flowering. The actual water requirement just prior to flowering was about two or three times the quantity required 10 to 15 days before flowering or the quantity required after flowering was over. Soon after flowering, there was a decrease in the water requirement.

Manuring was helpful not only in enhancing yields but also in lowering the water requirement. It was further noted that plants receiving farm-yard manure showed a lower water requirement than those receiving artificials like ammonium sulphate.

Once the rice plants had got well established they did not need standing water, but only a moist soil surface for optimum growth and yield. In pot-cultures water-logging was found to retard growth and tillering, but this aspect needs confirmation from field trials.

Assam: Experiments (2) carried out at the Karimganj Farm, to find out the water requirements of rice under varied conditions, showed that (1) the water requirement was somewhat higher in loams than in clayey soils and(2) the water requirement was found to be the least in unmanured plots and the highest in plots treated with Ammophos.

In Bengal, the minimum amount of water for a successful crop of rice was found to be 40 inches of total depth. A certain reduction in the transpiration rate was observed in the case of rice plants manured with phosphates and it was also noted that in years of deficit rainfall, phosphates were definitely helpful in maturing a crop that would otherwise suffer from insufficient moisture.

It was also noted that excessive watering in the early stages of growth was detrimental to tillering in the case of *aus* or autumn paddy, but during the flowering stage frequent watering was necessary.

Similar investigations by Sen (4) in the Calcutta University, have shown that plant height increased with the height of water standing in the field but standing water suppressed tiller formation in rice, the number of tillers decreasing progressively with an increase in the depth of standing water allowed. When the field was allowed to crack by drying out, flowering was delayed in *aus* paddy. Flooding the field after transplanting for a period of three weeks for *aus* varieties and somewhat longer for *aman* or winter varieties that have a longer duration, followed by subsequent de-watering, was beneficial to crop growth but during the later stages of growth, drainage was essential for proper aeration.

The optimum water supply for maximum yields was found to vary with different varieties of rice.

Hector (5) showed that the transpiration rate was a varietal characteristic which remains fairly constant for any given variety over a wide range of moisture levels. The rate of transpiration per unit area of leaf surface was markedly different between two varieties—one early and the other late, that were studied. The transpiration rate was higher in the early type. In the early type, the ratio of leaf to root was much larger than in the late type and further the stomata, though nearly the same in number per unit leaf area, were also demonstrably larger in size.

Experiments at Cuttack in Orissa (2) indicated that where irrigations were given in addition to rainfall, the paddy yields were improved. Thus, two three and four inches of water per acre were supplied to broadcast winter rice, in addition to the usual rainfall that was received during the growth period and it was found that 2 inches of "extra water" gave the best yields.

In Madhya Pradesh (3), experiments were carried by Bal (6) with medium and long duration varieties, growing under three conditions namely, (1) with standing water, (2) watered when needed and (3) no irrigation, and in two types of soils "Dorsa" clay loams and in "Matasi" sandy loams. The best yields were obtained from the late variety growing in standing water, both in the clay loams and sandy loams. In very heavy soils however, the rice crop showed better growth under well-drained conditions rather than when grown in standing water.

In Bombay, the water lost by transpiration during the life cycle of the paddy plant was found to be equivalent to nearly 25 inches of rainfall, whereas Singh and his co-workers at Banaras calculated that the quantity used up in transpiration and evaporation amounted to 27·4 inches of rainfall. In Assam, the experiments indicated that transpiration rate was closely following the fluctuations in daily temperature.

This type of evidence does not however clarify the question as to why a wet-puddled and submerged condition are necessary for good growth in rice. It has been suggested that such submerged condition provides certain constituents that are not available in semi-dry or "merely moist" conditions, one such constituent being silicon.

In Madras, irrigation experiments have been carried out by the Agricultural Department in this State, first to ascertain the quantity of water required by crops and then to find out the details of time and quantity of water needed, to secure the maximum yields. In the case of rice the total quantity of rice water was determined in the first stage and in the second epoch the best method of distributing a definite quantity of water over the life-time of the rice crop was sought to be determined.

Some of the early experiments were conducted in ryots' fields; some were with flow irrigation from canals, while others were carried out with irrigation from wells. The aim of these early experiments was to find out how much water was needed and at what intervals it should be supplied for different crops like paddy, cholam, ragi, cotton, cumbu, groundnut and sugarcane. Later on, the experiments were confined to Agricultural Research Stations with larger areas and a more detailed set of treatments.

The table below gives the duty of water for different crops at different stations in the Madras State (3), representing different tracts and regions. The duty of water is the irrigation work which a given quantity of water can perform and is usually shown as the number of acres on which a crop can be irrigated by a continuous flow of water at the rate of 1 cubic foot per second.

TABLE I

Duty of water for various crops

Agricultural Research Station	Region	Soil	Crop	Period of growth	Average duty of water
Maruteru	Godavari and Kriishna deltas	Heavy, black clayey soil	Sugarcane	Mar–Jan.	107
			Banana.	do. do.	136
			Rice first crop.	June–Dec.	81
			Rice second crop.	Feb–Mar.	54
Aduthurai	Cauvery (old delta)	Light clay (alluvial loam)	Rice-Kuruvai	July–Oct.	68
			,, Samba	Aug-Jan.	76
			,, Thaladi	Oct-Feb.	80
Pattukottai	Cauvery (New Delta)	Sandy loam	Rice-Kuruvai	July–Oct.	37
			,, Samba	Aug–Jan.	47
			,, Thaladi	Oct–Feb.	67
Coimbatore	Canal fed, supplemented by wells	Black cotton soils—of a lighter type	Rice	Aug–Feb.	51
			Ragi	May–Sep.	130
			Sorghum	May–Sep.	120
			Cotton	Oct–April	190
Lower Bhavani	Project area	Loose, gravelly soils.	Rice	Aug–Feb.	40
Siruguppa	Tungabhadra Project area	Heavy, black cotton soils	Rice	July–Dec.	60
			Sugarcane	Mar–Feb.	99
			Bajra	June–Dec.	103
			Ragi	July–Oct.	126
			Groundnut	July–Oct.	156
			Sorghum	June–Sep.	163
			Wheat	Nov.–Mar.	235
			Cotton	Aug–Mar.	265

The quantity of water needed for rice varies according to the nature of the soil and locality, the state of the land prior to and at the time of planting the crop, and the quantity and distribution of the rainfall that is received during the life time of the crop. In certain special tracts as in the sandy loams of the Pattukottai area, the duty of water for the *Kuruvai* crop between July and October is as low as 37, whereas in the deltaic areas of Maruteru, where there is an assured supply of irrigation water and also good rains between June to October, the duty of the first crop of paddy may be as high as 81. Even at Pattukottai, and at Aduthirai too, the *samba* and *thaladi* crops have generally a higher duty of water than the *Kuruvai* crops.

At Coimbatore, where a long duration *samba* type of rice is grown under tank-fed irrigation, an average of 51 inches of water is required per acre in addition to the rainfall that is received during the growth of this crop.

The duty of water in the heavy black soils of the Tungabhadra Project area works out to 60, whereas in the loose gravelly soils of the Lower Bhavani Project area, the duty is only 40 for rice.

The next series of experiments, which were continued from 1938 to 1942 are summarised in Table II. The results of these experiments, though they are not very consistent, still serve to indicate the following conclusions:—

At Maruteru Agricultural Research Station (West Godavari System) the results were not significant for the first crop in any year but in the second crop season, it was noted that the yields were in proportion to the quantity and frequency of water supplied. The control plots which received the largest quantity of water nearly always gave the highest yields. A similar result was noticeable in the sandy loams of Pattukottai in the Cauvery Mettur Project area, though here too, the results were not significant in all the seasons. At Aduthurai, due to the fact that the plots where the experiments were laid out were all more or less at the same level, water that was let into any one plot, got distributed by mere seepage to practically all plots, so that no conclusions are possible from the experiments at this Station.

At Coimbatore, where the water supply for the rice crop is from tank-fed channels, supplemented by well irrigation, the differences were not significant in three out of five years, i. e., when the rainfall was normal or above normal. In years of deficient rainfall however, treatment A i. e., 2″ irrigation given at 3-day intervals, gave the best yield and equalled the yield from plots that had standing water throughout. Other treatments, receiving water at wider intervals recorded lower yields.

TABLE II

First set of experiments

Treatments

A — 2″ in 3 days
B — 2″ in 6 days
C — 2″ in 9 days
D — 4″ in 6 days
E — 4″ in 12 days
F — 4″ in 18 days
G — Normal for 4 weeks and 4″ in 12 days
H — Normal — standing water

Results

Yield of grain — Single crop
Paddy Breeding Station, Coimbatore.

Year	A	B	C	D	E	F	G	H	Z test P—0·05	C.D. P—0·05
1938—39	2786	2458	2228	3094	2425	2259	3016	2915	Yes	558 S
1939—40	2840	2663	2319	2819	2566	2394	2719	1300	No	
1940—41	2106	1750	1806	2119	1925	1663	1806	1950	No	
1941—42	4320	3976	3117	4357	3121	2940	3714	4222	No	

Agricultural Research Station
Maruteru—First Crop

Year	A	B	C	D	E	F	G	H	Z test P—0 05	C.D. P—0·05
1938—39	3100	3025	3016	2981	3190	2975	3086	3152		
1939—40	2352	2481	2410	2291	2349	2057	2412	2463	Yes	47·3
1940—41	2863	2844	2370	2710	2653	2233	2612	3025	Yes	88·8
1941—42	2370	3124	2743	3383	3227	2712	3161	3434	Yes	370·3

In a second series of experiments, from 1943 to 1947, (at the Agricultural Research Station, Aduthurai on *Samba* paddy), the treatments were slightly modified, as indicated in Table III.

TABLE III

II. Second set of experiments—Treatments

A 1″ minus rainfall ... Once in 3½ days
B 1″ ignoring ,, ... ,, 3½ ,,
C 2″ minus ,, ... ,, 3½ ,,
D 2″ ignoring ,, ... ,, 7 ,,
E 2″ minus ,, ... ,, 7 ,,
F 3″ minus ,, ... ,, 7 ,,
G 4″ minus ,, ... ,, 7 ,,
H 3″ of water at all times (Control).

Yield of grain

Year	A	B	C	D	E	F	G	H	Z test P—0·05	C.D. P—0·05
				Paddy Breeding Station, Coimbatore.						
1943—44	1763	1825	1616	1928	1734	1481	1913	2047	No	
1944—45	2467	2755	2717	1713	2656	2725	2931	2825	No	
1945—46	2949	3107	3107	3012	3201	2918	2969	2069	No	
				Agricultural Research Station, Aduthurai *(Samba)*						
1943—44	2320	2350	2250	2360	2350	2350	2390	2370	No	
1944—45	2530	2627	2506	2612	2400	2450	2353	2533	No	
1945—46	3806	4130	4250	3965	3900	4030	4940	4100	No	
				Agricultural Research Station, Maruteru.						
1943—44										
I crop	3118	3094	3133	3091	3245	2678	3004	3311	No	
II crop	2451	2486	2474	2325	2302	2429	2354	2599	No	
1944—45										
I crop	3211	3289	3276	3070	3063	3298	3131	3189	No	
II crop	2289	2320	2381	2238	2333	2054	2327	2522	No	
1945—46										
I crop	2200	2336	2328	2314	2340	2445	2395	2476	No	
II crop	1670	1697	1932	1464	1472	1692	1562	2035	Yes	258
1946—47										
I crop	2914	2911	3053	2914	2960	2992	3262	2982	No	
II crop	1568	1587	1372	1430	1352	1381	1442	1783	Yes	265

These trials were carried out at Coimbatore, Aduthurai and Maruteru. The Coimbatore trials were inconclusive on account of the failure of monsoons. At Maruteru, the control i. e., "depth of water kept standing at all times", gave the highest yields in two first-crop seasons and was on a par with the treatments receiving water at 3½ days intervals. All the treatments where water was supplied at 7-day intervals, recorded poorer yields. At Aduthurai, the results of this series of experiments too, were inconclusive in all the three years of trial.

In a third set of experiments commenced in 1948, the time of planting was varied and the water allowed was given to different depths, this quantity being further split up into different phases of crop-growth. The main indications from this series were that the yields were more dependent on the time of planting, than on the quantity of water supplied. The inter-actions between different planting periods and different quantities of water supplied were also not significant.

Another set of experiment was carried out for 2 seasons (1946 and 1949) to find out how far drying out of paddy fields would affect the ultimate yields as compared to the ryots' practice of keeping a film of water standing throughout the season. This intermittent drying out was suggested as an anti-malarial measure to aid in destroying mosquito larvae that are usually found in the standing water in rice fields. The results indicated that yields were the highest in plots where water was always kept standing. In the 1949 season, keeping the fields 'dry' for two days appeared actually to improve the grain and straw yields. Keeping the field dry for three days before letting in water, had no adverse effect on yields, but drying for 4 days was slightly harmful, while drying for 5 days was definitely so, lowering the yields by nearly 20% from controls. A similar trend was noticeable in the straw yields also and it may be concluded therefore, that paddy fields should not be kept without standing water for more than three days at a stretch.

Irrigation experiments on rice have also been conducted at the Siruguppa Agricultural Research Station in the Tungabadhra Project Area. These showed that irrigating the heavy, black, clayey soils of the the Tungabadhra Project area did not lead, as apprehended at the outset, to any rise of deleterious salts from the sub-soil to the surface as a result of irrigation. It was also noted that a single crop of long duration rice could be grown to better advantage in the Tungabhadra Project area, than a double crop of two short-duration varieties. Where sugarcane was grown in rotation with rice, both the crops were seen to be benefited on account of the fallow period that intervenes once in two years, between September to June.

Another observation was that better yields could be secured when rice was grown in the well-drained, shallower soils in the Tungabhadra Project area, than on the stiff, black clayey soils where drainage was more difficult. In order to bring the land into proper condition, any system of cropping and particularly so for rice, must include deep ploughing and drying out of the soil during the fallow period. To this end it is necessary to devise an integrated system of co-operative planning ~~in the~~ in the Tungabadhra Project area, according to a zonal pattern, so that soil moisture could be maintained at optimum levels at the right time, in the various places to be served by the Tungabhadra Project. And for this, sufficient experimental data and basic knowledge regarding the water requirements of different crop plants are essential, since wastage of water would only add to the sub-soil reservoir and lead to water-logging and eventually reduce the usefulness of the irrigation system itself.

Discussion: It would be noted from the above summary of work that the experiments so far conducted have all been more or less on empirical lines. Numerous factors that are concerned in the water requirement of crops have been omitted from consideration. The main results from all the experiments reviewed so far are only that (1) rice needs more water than any other agricultural crop, (2) that more water is needed by a rice of longer dura ion than a short duration type, and (3) that the quantity of water needed depends to a large extent on the type of soil as well. An integrated picture of the behaviour of the rice plant in regard to its water requirement is still lacking and a good deal of further study is still needed to attain this end. The main lines along which studies may be carried out are indicated below.

Three aspects are involved in any study of the water requirements of crops, namely the soil, plant and the atmosphere and none of them may be ignored in any scheme of investigation on this subject, particularly when paddy is the crop plant that is proposed to be investigated. The rice plant is in several respects rather peculiar and differs from other crops in requiring a special set of soil-water conditions before it can thrive.

In spite of the fact that it is one of the oldest and best studied among crop plants, a number of problems remain still unsolved, such as :—

(1) how far puddled conditions are essential or advantageous for rice growth,

(2) how far the presence of an algal film is necessary for good growth of rice

(3) the inter-relations of these with the water requirement of rice plants at different stages of the life cycle.

(4) Basic knowledge regarding the water requirements of all the different varieties (or at least the most important types) under a standard set of soil, moisture and atmospheric

conditions (i. e., temperature, light and humidity) should be gathered first, before any attempt is made to extend the study to the variations in water requirements brought about by a different set of soil and moisture conditions, and also the effect of different manurial treatments.

In view of the fact that no amount of care can duplicate in pot cultures the same conditions that exist in the field, the findings from pot culture studies have necessarily to be verified and confirmed by field tests. However pot-culture studies may be made to approximate to field conditions by making use of lysimeters of large surface and soil capacity. A further advantage in these will be that they can be kept under controlled conditions of light, temperature and humidity so that the experiments of one season can be repeated in other seasons with a greater expectation of reproducible results. Under such controlled conditions, observations on the micro-climate in and around the crop can be recorded and conclusions drawn therefrom, within a shorter period of years than under field conditions.

It is therefore suggested that this line of investigation is one that merits serious attention if the problem of utilising the available water supply to the best advantage in crop production in general and rice production in particular, is to be solved in a satisfactory manner.

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BIBLIOGRAPHY

1. McKenzie Taylor ,et al — (1941) — Ind. J. of Agri. Sci. Vol. XI.
2. Singh, et al — (1935) — Proc. of Ind. Acad. Sci. Series I-B., P. 472.
3. Annual Reports of Rice Research Schemes and Annual Reports of States — (1930 to 1945).
4. Sen — (1937) — Ind. J. of Agri. Sci. Vol. VII P. 89.
5. Hector — (1920-1926) — Annual Reports of Bengal Dept. of Agri.
6. Bal, D. V. — (1932) — Agri. and L. Stock in India Vol. II.
7. Report on water requirements of Rice, Iowa State Bulletin — (1939).