

Evapotranspiration of upland paddy

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सार — उपरिभूमि धान की जल्दी पकने वाली किस्मों (85-116 दिनों की अवधि) के लिए, संचयी वाष्पोत्सर्जन 430.5 से 598.9 मि०मी० के पराम से पाया गया था। फसल अवधि पर औसत दैनिक वाष्पोत्सर्जन 4.67 से 6.07 मि०मी० प्रति दिन पाया गया था, जो विभिन्न किस्मों और स्थान पर आधारित है। बोधा लगने, विकसित होने और गुपन की अवस्थाएं संवेदनशील चरण अवस्थाएं कही जा सकती हैं क्योंकि ये जल खपत की जरूरत अवस्थाएं हैं। फसल की जल प्रयोग क्षमता 2.31 से 8.34 कि०ग्रा०/हे०/मि०मी० के बीच परिवर्तित होती है।

ABSTRACT. The cumulative evapotranspiration for early maturing varieties (duration 85-116 days) of upland paddy was found to be in the range of 430.5 to 598.9 mm. The average daily evapotranspiration over the crop period was found to be 4.67 to 6.07 mm/day depending upon varietal type and location. The booting, heading and flowering stages are critical stages as these exhibit peak period of water consumption. The water use efficiency of the crop varied from 2.31 to 8.34 kg/ha/mm.

1. Introduction

In India, out of 38.4 million hectares, the total area under rice cultivation, approximately 2.4 million hectares is under upland cultivation and much of future expansion of rice land will probably be in upland rice.

Not very much is known about water requirement of upland rice and its water use efficiency. Furthermore, it is difficult to generalize the available information because of variation in soil properties, topography, length of growing period, varieties, local agronomic practices and environmental conditions. The objective of the present study is to present the weekly and cumulative experimental data on actual evapotranspiration (ET) losses during different phenological stages of the crop to compare ET with pan evaporation (EP) and obtain coefficient (ET/EP ratio) to analyse its march with crop growth and to present water use efficiency (WUE) of upland paddy. The investigations were carried out at Varanasi (25°20' N, 83°00' E), Ranchi (23°20' N, 85°20' E) and Bhubaneswar (20°20' N, 85°45' E).

2. Material and methods

The data used for the present study include : (a) lysimetrically observed ET values, (b) the observations taken on the crop to delineate the different phyto-phases and (c) meteorological observations, like evaporation, rainfall, wind, temperature etc recorded at the nearby agrometeorological observatories.

Gravimetric lysimeter employed for ET measurement consist of a soil tank of size 1.3m × 1.3m × 0.9 m in which soil is back-filled. The tank rests on the platform of a two tonne capacity dormant weighing machine

which is mounted on the RCC foundation constructed in a pit in the middle of the field. Lysimeters of 1 m³ size have been recommended by McIlroy (1957) and many other workers for raising short crops. The lysimeters used meets this requirement but has following limitations :

- (i) Restricts root development due to limited soil of 75 cm depth,
- (ii) Despite sufficient guard ring area clothesline effect cannot be ruled out,
- (iii) Difference in physical characteristics of soil profile and
- (iv) Inhomogeneity in the crop stand in lysimeter and the surrounding plot.

Early maturing varieties (crop duration 85 to 116 days) were cultivated employing recommended cultural and plant protection practices. At Varanasi [soil type : sandy clay loam; moisture storage of 75 cm deep profile at field capacity (FC) = 237 mm and water storage and Permanent Wilting Point (PWP) = 63 mm] variety *Cauvery* was cultivated for a five years, viz., 1978, 1979, 1981, 1982 and 1983. The crop was shown around mid-July and harvested around October end. At Ranchi [Soil type : clay; moisture storage at FC = 255 mm & moisture storage at PWP = 127 mm] variety *Kiron* was cultivated for two years (1977 and 1978) and variety *Brown-Gora* was cultivated for three years (1979, 1980 and 1983). Sowing of *Kiron* was done in 3rd week of June and harvesting accomplished during

TABLE 1

Water use efficiency, cumulative ET and cumulative EP

Station	Variety	Crop duration days	Cumulative ET (mm)	Average daily ET rate over crop duration	Cumulative EP (mm)	W.U.E. (kg/ha/mm)
Varanasi	Cauvery	144	598.9	4.76	511.7	4.77
Bhubaneswar	CRM-13	85	510.6	6.07	373.1	5.78
	DR-92	98	430.5	4.69	322.7	3.90
Ranchi	Kiron	111	567.0	4.76	454.3	8.34
	Brown-Gora	116	464.5	4.67	452.8	2.31

second week of October. Crop duration for *Brown-Gora* was from early July to mid-October. At Bhubaneswar [soil type: clay loam; moisture storage at FC=286 & moisture storage at PWP=152 mm] CRM-13 (years 1979 and 1982) and DR-92 (years 1981 and 1983) were sown during June-end to be harvested during September-end. The crop at all the stations was rainfed, however, light irrigations were given during dry spells to avoid water stress till it entered senescence. Daily observations of ET were recorded at 0700 LMT. After harvesting yield was measured and Water Use Efficiency (WUE) worked out.

3. Results

The results in respect of cumulative ET, average daily rate of ET cumulative EP and water use efficiency at Varanasi, Bhubaneswar and Ranchi are presented in Table 1.

It is seen from Fig. 1 that during the initial week after sowing the average daily ET was 5.2 mm/day for variety *Cauvery* at Varanasi. Further, it decreased to 2.2 mm/day, mainly due to drying of top soil layer. The maximum rate of 7.3 mm/day was obtained during booting stage. Thereafter, the rate of ET started declining and touched the lowest value of 1.3 mm/day at the end of ripening. Although, there were many ups and downs in ET curve from seedling to flowering, the same went hand in hand with fluctuations in atmospheric demand for water vapour as designated by the EP curve. It is also seen that the ratio ET/EP was more than unity almost during entire

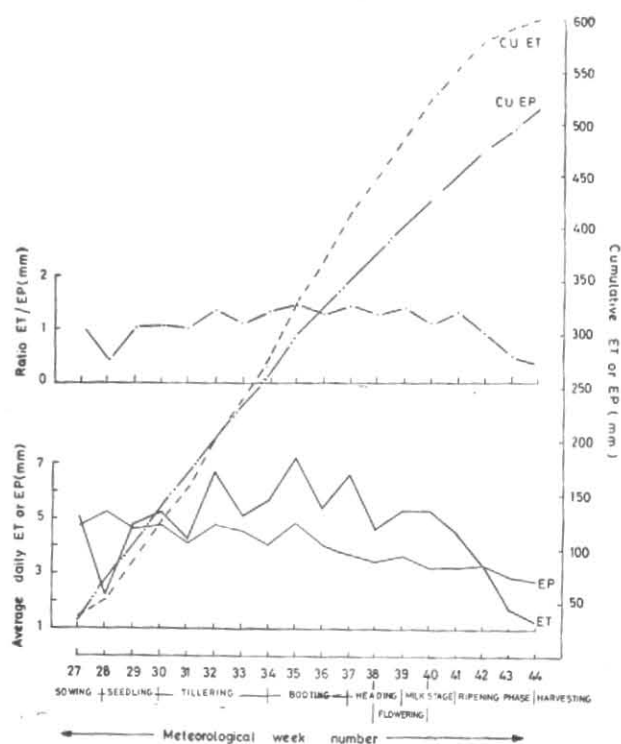


Fig. 1. Evapotranspiration, evaporation and ET/EP ratios for upland paddy (Variety *Cauvery*) at Varanasi

vegetative and reproductive phases. The same was maximum (1.50) during the booting stage, thereby delineating the booting phase to be the period of peak water consumption.

At Ranchi, for variety *Kiron*, the daily ET was as low as 1.4 mm/day in the first week after sowing and it rose to 3.4 mm/day during beginning of seedling stage. There was no decrease in ET rate subsequent to sowing during early seedling stage as was the case at Varanasi. This may be due to the high organic matter content of the clay soil which facilitates regular upward transport of water vapour from lower to upper strata of soil to cause evaporation even when uppermost layer is dry. ET rate varied in the range of 3.4 to 5.2 mm/day during the seedling stage and enhanced further in the range of 4.1 to 6.2 mm/day during tillering phase. The peak value of 7.5 mm/day was observed during late heading/early flowering phases. This period, therefore, could be identified as critical period from the point of view of water consumption. The rate decreased sharply after the flowering phase through milk stage and ripening. During reproductive phases the variation in ET rates shows ups and downs in contrast with the EP rates. This may be due to higher soil moisture available for ET. For this variety, the average rate of ET was 4.8 mm/day over the entire span. The cumulative ET values were lower than cumulative EP till maximum tillering and, therefore, cumulative ET exceeded the cumulative EP. The ET/EP ratio was less than unity during first three weeks and last two weeks of the

crop life. The ratio was highest (*i.e.*, in the range of 1.47 to 2.20) during reproductive phase with its peak at heading/flowering stage.

In case of variety *Brown-Gora* at Ranchi, the cumulative ET was lower than cumulative EP prior to the end of tillering, and greater thereafter. In the initial week the ET rate was 2.0 mm/day and became 5.0 mm/day in the beginning of the seedling phase. It varied from 3.7 to 6.2 mm/day during the vegetative growth of crop plants. It was between 4.8 and 6.8 mm/day during reproductive stage and was reduced to 2.5 mm/day in the last week. The ratio ET/EP was less than unity during the first two and last three weeks of crop life. It was highest (between 1.41 and 1.79) during the reproductive phase.

At Bhubaneswar, the daily ET rate for variety CRM-13 was as high as 4.1 mm/day in the beginning which decreased to 2.7 mm/day after two weeks of sowing. By the end of vegetative phase it increased to 7.4 mm/day in a steep manner. The rate was maximum and prevailed between 6.7 and 10.3 mm/day in the reproductive phase. Finally, during ripening phase, the rate decreased. However, it remained considerably high (4.9 mm/day) till the end of crop season. During the period between beginning of active vegetative growth and end of reproductive phase, the ET and EP showed similar trend, though the magnitude of ET was much higher. The ET/EP ratio was less than 1.00 during initial three weeks after sowing. During reproductive phase, it varied between 1.54 and 2.45. Later, it declined during ripening phase, but as the ET rate during this phase was higher than contemporary EP, the ratio was 1.22 even at the time of harvest.

In case of variety DR-92 grown at Bhubaneswar, the rate of ET was 3.3 mm/day in the first week after sowing and it decreased to 2.6 mm/day in the following weeks. During vegetative phase, it ranged between 3.4 and 5.1 mm/day. The period of peak water consumption was seen during reproductive phase when the ET rate touched the value of 7.7 mm/day. During ripening phase the ET rate ranged between 4.1 and 6.4 mm/day which was comparatively higher. Barring the first three weeks the value of ET/EP ratio remained above unity, the peak value being 1.88 which was observed during the reproductive phase. The ratio, though decreased in the maturity phase like in case of variety CRM-13, it remained at 1.21 at the time of harvest.

4. Discussion

The ET data on five early maturing varieties of upland paddy collected at Varanasi, Ranchi and Bhubaneswar reveal that their consumptive water requirement varies from 430 mm to 600 mm. The seasonal ET losses for different varieties are presented in Table 1.

In Israel, water requirements of upland paddy was observed to be 450-500 mm (Hart-Zook 1961). At Cuttack the consumptive use for upland paddy varieties *Bala* and *Cauvery* was reported to be 449 and 514 mm respectively (Anonymous 1965 and 1977). At Nellore, Rao *et al.* (1976) found cumulative ET for low-land kharif and summer paddy to be 635 and 625 mm respectively.

However, for summer crop at Canning, it was 470 mm only. Irrigation requirement for low-land summer crop in California and Texas were found to be 1500-1800 mm (Grist 1965) and 800-1200 mm (Hodges 1957) respectively. In Egypt, 1500-1700 mm of water is required to be applied for low-land rice (Adair and Angter 1955). The total water loss from irrigated low-land paddy during crop season was estimated to be 1240 mm by Kung (1971).

It is seen from the preceding discussion that the water losses observed from upland paddy are much lower than those reported for low-land culture. It is mainly due to : (i) no standing water is required for upland culture, hence restricted availability of water for evaporation, (ii) to meet the oxygen demand in anaerobic conditions, the low-land paddy varieties have a genetic system of transporting oxygen from shoot to root (Van Raalte 1944, Armstrong 1970). This system is less efficient in upland varieties (Arikado 1959). Hence, in low-land paddy, stomata are open for longer period to facilitate the gas exchange and thereby becoming vulnerable to higher transpiration and (iii) moisture stress condition in upland culture lead to reduction in ET rate.

Study of march of ET/EP ratio reveal the ratio was less than unity during early vegetative growth stage and it increased along with vegetative growth of the crop and become more than unity. The reason, obviously, could be the rapid increase in the effective transpiring surface area. During the reproductive phase, when water needs are maximum, the ratio attained the peak value of about 1.50. The value of the ratio above unity could be further explained in terms of energy balance consideration. The crop canopy acts as a better sink for advected energy than the pan. Unfortunately, it is difficult to quantify the differential energy supplies to these surfaces by horizontally transferred energy which is certainly significant in arid and semi-arid zones.

An idea about critical water demand stage of the crop can be obtained by the amount of water consumed during various phases of crop's life cycle. The rate of ET increased with successive growth stages attaining a peak during early reproductive stage. This trend was observed for all the varieties used at different stations. Hence, booting, heading and flowering can be designated as critical stages as these exhibit peak period of water consumption. During this period crop may suffer water deficit when there is a moisture stress or on hot, dry and windy days. Matsushima (1968) also found that the rice plant is sensitive to drought from cell division stage to flowering stage. Similarly, Murato (1961) observed that the photosynthesis of rice leaves at booting stage was closely correlated with leaf water content and, therefore, any water stress at this stage lead to lower yields.

The average daily ET over the crop period was found to be in the range of 4.7 to 6.1 mm/day depending upon varietal type and location. This is much lower than the average daily losses in irrigated low-land rice as reported by Kung (1971) which are in the range of 5.6 to 20.4 mm/day. Hence, based on average daily ET rate, one can say that upland paddy cannot be successfully grown in areas receiving weekly rainfall less

than 35 mm for a minimum of 15 weeks. This requirement is based on average daily rate over the entire crop period and does not include percolation losses and water need for land preparation etc which must also be accounted suitably. These water needs relate to the average for early maturing, semi-dwarf varieties. Selection of variety at a particular location should be made keeping in view the growth duration, soil type and rainfall distribution. For upland rice short duration cum drought hardy varieties should be chosen to match the available precipitation regime.

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