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Water use pattern of rice and its relationship with radiation over coastal Andhra Pradesh

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सार – इस अध्ययन में, नेलूर में धान की फसल में हुई कुल वाष्पनिक हानि की विभिन्न अवस्थाओं में दैनिक औसत वाष्पन वाष्पोत्सर्जन (ई.टी.) और उसके सहायक होने के विषय में चर्चा की गई है। वाष्पन वाष्पोत्सर्जन/वाष्पन दरों (ई.टी./ई.पी.) और प्रतिरोपण के उपरांत के दिनों की संख्या के बीच निदर्शों को विकसित किया गया है। फसल में फूल आने की अवस्था के दौरान तीनों की ऋतुओं में ई.टी./ई.पी. की औसत दर खरीफ के मौसम में अधिकतम पाई गई है। कुल लघु तरंग विकिरण (आर.एस.) के वाष्पन–वाष्पोत्सर्जन के अनुपात का विश्लेषण किया गया है और यह अनुपात फसल में फूल आने की अवस्था के दौरान अपने चरम मानों पर पहुँच जाता है।

ABSTRACT. In this study the mean daily evapotranspiration (ET) and its contribution in different phases to the total evaporative loss have been worked out for paddy at Nellore. Models have been developed between evapotranspiration/evaporation rates (ET/EP) and number of days from transplanting. ET/EP ratio has been found to reach it peak during the flowering stage in all three seasons. The mean ET/EP ratio is the highest in kharif season. Ratio of evapotranspiration (ET) to total short wave radiation (R_s) has been analysed and the ratio is found to reach its peak value at flowering stage of the crop.

Key words – Evapotranspiration, Transplanting, Flowering, Short wave radiation.

1. Introduction

Rice is a heat loving plant and it originated somewhere between the areas extending from Southern India to Indo-China. It requires high temperatures, an ample water supply, and high atmospheric humidity during the growth period. Rice has been cultivated in India atleast past 7000 years. It is the staple food for major portion of the population. The yield of rice is considerably influenced by the behaviour of south-west monsoon over most parts and north-east monsoon in south India. In view of its importance, rice research has gained lot of impetous during past 40 years. This has lead to vast improvement, mostly genetic, in rice production which now stands nearly 70 million tons. It is therefore, felt that science oriented technology has still a major role to play in further increase of rice production in the country. There is still scope for breeding new varieties of shorter duration with less consumptive use of water and stress tolerant during critical phases.

India Meteorological Department, since 1976 has established a network of 39 evapotranspiration stations over India to study the water requirement of rice and other crops. The amount of data thus collected has helped better understanding of crop-water-requirements. Dastane *et al.* (1966) studied water use pattern for wetland paddy at New Delhi and Chaudhury (1966) for Orissa. Based on the data collected in the initial years of the scheme, the evapotranspiration of paddy was studied at Nellore and Cannning by Subbarao *et al.* (1976) who found that reduction in crop transpiration to be more pronounced at Nellore than at Canning. Ghildayel and Tomar (1976) found that wetland rice at Pantnagar transpires about 990 mm of water in its growth cycle. Maske and Rathore (1988) studied the ET/EP ratio for upland rice at Bhubaneshwar, Ranchi and Varanasi. Das *et al.* (1994) found that weekly water use and crop coefficients for kharif rice at Canning (West Bengal) during flowering are found to be maximum compared to other phases.

This study attempts to determine the water requirement of rice and its relationship with radiation component during different phases of its growth. Quantitative understanding of the water dynamics of the rice system, in particular with respect to evaporation and radiation would help evaluating suitability of locations for a particular paddy specie.

TABLE 1

Statistics on seasonal crop evapotranspiration and evaporation rainfall etc

Year	Season	Variety	Date of Transplanting	Duration (days)	Consumption ET (mm)	EP (mm)	PET (mm)	Seasonal rainfall (mm)	R_s (mm)
1976	Summer	IET - 2508	19 Feb 1976	92	680.6	574.0	919.2	0.0	919.2
1978	Summer	IET- 2508	24 Mar 1978	81	708.8	655.5	657.4	17.4	796.3
1987	Summer	IET – 1444	8 Mar 1987	77	735.5	595.7	634.0	8.8	634.0
1988	Summer	NLR - 1444	22 Mar 1988	66	585.4	457.1	520.7	21.6	520.7
1977	Kharif	NLR – 9674	27 Aug 1977	132	646.3	556.1	698.6	593.5	1071.2
1978	Kharif	NLR – 9674	22 Sep 1978	113	551.8	425.4	505.6	638.1	796.3
1979	Kharif	NLR – 9672	29 Aug 1979	132	640.8	503.5	644.5	762.5	1047.6
1982	Kharif	NLR – 9672	28 Sep 1982	111	785.3	626.1	414.5	496.8	877.2
1983	Kharif	IETS – 656	27 Sep 1983	93	598.9	467.7	428.0	522.1	677.1
1986	Kharif	NLR – 9674	23 Sep 1986	153	944.2	770.9	758.7	803.1	1210.0
1987	Kharif	IET – 1444	2 Jun 1987	98	868.0	784.4	777.9	202.4	820.5
1987	Kharif	NLR – 7994	19 Sep 1987	105	501.0	374.7	485.9	1047.1	830.5
1993	Kharif	NLR-3357	16 Jun 1993	99	1330.0	750.0	473.0	176.0	825.0
1994	Kharif	NLR-3356	25 May 1994	112	974.0	817.0	581.0	229.0	860.0
1980	Rabi	NLR – 9674	3 Oct 1980	120	609.0	481.9	517.3	622.3	956.4
1981	Rabi	NLR – 9674	6 Oct 1981	118	816.9	627.8	514.0	630.6	946.7
1986	Rabi	NLR - 9674	16 Oct 1986	120	562.3	474.2	498.1	723.8	929.4

2. Materials and method

Data collected at experimental farm at Nellore from 1976 to 1994 forms the basic data set in the present study. Though paddy is raised at the station in all the three crop seasons *viz.*, kharif, rabi and summer, data for all the three seasons were not available for each year. Details about the variety duration, water use, rainfall etc. is given in Table 1. The evapotranspiration (ET) was measured through volumetric lysimeters located in the crop field and maintained by India Meteorological Department. This was used to determine consumptive water use by the paddy plant. The evaporation (EP) values refer to standard US open pan evaporimeter.

The incoming solar radiation (R_s) was calculated indirectly from number of sunshine hours, using Angstrom standard formula :

$$R_s = (a + b\ n/N)\ R_A$$

where R_A is the theoretical amount of radiation that would reach the earth's surface in the absence of the atmosphere, n is the actual duration of sunshine hours, N is the maximum possible duration of sunshine and a and b are constants. The sunshine hours were recorded by Campbell-Stroke Solarimeter.

The values for a = 0.32 and b = 0.45 for the location have been taken as those given by Ganesan (1970) for Indian locations.

3. Results and discussion

3.1. *Consumptive water use*

Rainfall mostly occurs at Nellore during kharif season and increasingly so in rabi. During summer, the crop is raised purely on irrigation. The water consumed by paddy during kharif was about 690 mm followed by 680 mm in summer. Subba Rao *et al*. (1976) observed that paddy at Nellore was 635 and 625 mm of water during kharif and summer. Least water use (660 mm) has been found during the rabi season. Pande and Mitra (1971) observed total ET loss at Kharagpur as 669 mm in rabi. The total evapotranspiration in the mean during kharif was 15 cm less than the precipitation while in rabi the water availability *i.e*. rainfall and evapotranspirative loss, nearly

TABLE 2

Mean weekly ET (mm)

Phase	After transplanting	Tillering	Flag leaf	Panicle emergence	Flowering	Fruiting	Maturity	Total
Kharif	52.8 (17.0)	46.5 (15.0)	43.2 (14.0)	47.0 (15.2)	51.0 (16.5)	34.5 (11.1)	34.7 (11.2)	309.7
Rabi	39.0 (14.3)	38.5 (14.2)	28.5 (10.5)	54.8 (20.1)	44.5 (16.4)	34.4 (12.6)	32.4 (11.9)	272.1
Summer	42.9 (9.9)	49.1 (11.3)	57.5 (13.3)	61.5 (14.2)	81.0 (18.7)	78.3 (18.0)	63.4 (14.6)	433.7

Figures in the parenthesis are the percentage of total ET

TABLE 3

Mean daily use of water (mm/day)

Phase	After transplanting	Tillering	Flag leaf	Panicle emergence	Flowering	Fruiting	Maturity
Kharif	7.0	6.4	5.7	6.7	6.7	5.2	5.0
Rabi	5.1	4.8	5.2	6.4	7.4	5.7	4.4
Summer	5.7	6.9	8.0	8.6	14.5	10.8	7.9

matched each other. With just 16 mm of rainfall in summer obviously the evapotranspiration far exceeds the precipitation in this season.

Table 2 contains the mean weekly ET during different phases of growth and its contribution to total water use. During kharif, between transplanting and tillering, the weekly water use is as high as 53 mm contributing to nearly 16% of seasonal water use. Though the weekly water use during flowering is slightly less as compared with transplanting stage, its contribution is maximum (*i.e.* 17.3%) during flowering because the canopy during this phase is fully developed. Similarly in rabi and summer seasons, the weekly water use during flowering stage are 20.1% and 21.2% respectively, although the maximum weekly water use occurs at panicle emergence during rabi season. During fruiting, in summer the contribution for ET to total water user remains substantial. Another noteworthy feature is that even at abscission state, paddy continues to consume as large as 15% of its total water use.

Maximum daily ET rate in various crop seasons is given in Table 3. During kharif, at transplanting ET rates are high (*i.e.* 7.0 mm) due to standing water in the rice field. The rates continued to be rather large even during maturity. Another remarkable observation is that after tillering stage, the ET rates in summer become much larger (1½ to 2 times) than that in the other seasons, perhaps the water demand during summer increases substantially due to higher temperatures and dry and strong desiccating winds.

3.2. *ET/EP ratio in relation to crop development*

A generalized growth rate ET/EP relation can be also derived from the data. For all the three seasons this is given in Fig. 1. The ET/EP ratio, as may be seen, exceeds 1.0 right from the beginning, since water is non-limiting. For the season as a whole ET/EP exceeded 1.2 in each season (cf. G. B. Pant, Univ. Report 1977). During the active growth phase of the crop particularly between flag leaf to fruiting when the crop is completely covering the ground, the ratio exceeds 1.25. The pattern is typically a single peaked one, occurring during flowering in all the seasons with a maximum value of about 1.6. The sharp decline after flowering in all the seasons with a maximum value of about 1.6 . The sharp decline after flowering is obviously associated with grain filling and maturity during which the leaves undergo fast senescence. The ET /EP ratio during summer is less than the other two seasons after flowering. Perhaps the excessive evaporation due to non-limiting irrigation water keeps the ET/EP ratio down.

The mean EP/ET ratio progressively decreases from 1.27 during kharif, to 1.25 in rabi and 1.21 in summer. These generally agreed with values given by Tomar and O'Toole (1979) for different rice variation in various

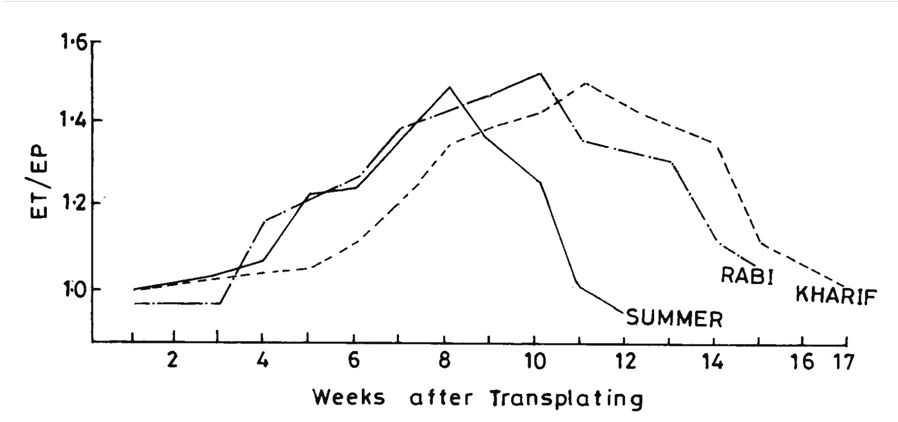

Fig. 1. Distribution of ET/EP against time of growth

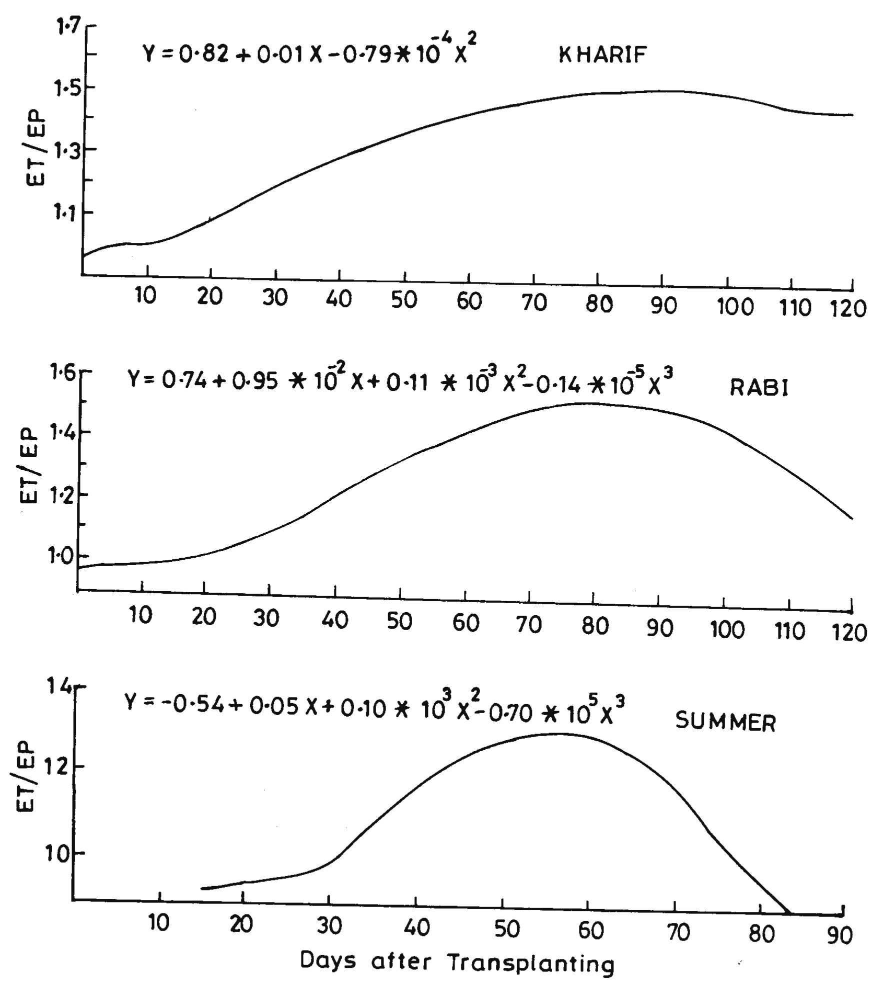

Fig. 2. Relationship between ET/EP and days after transplanting

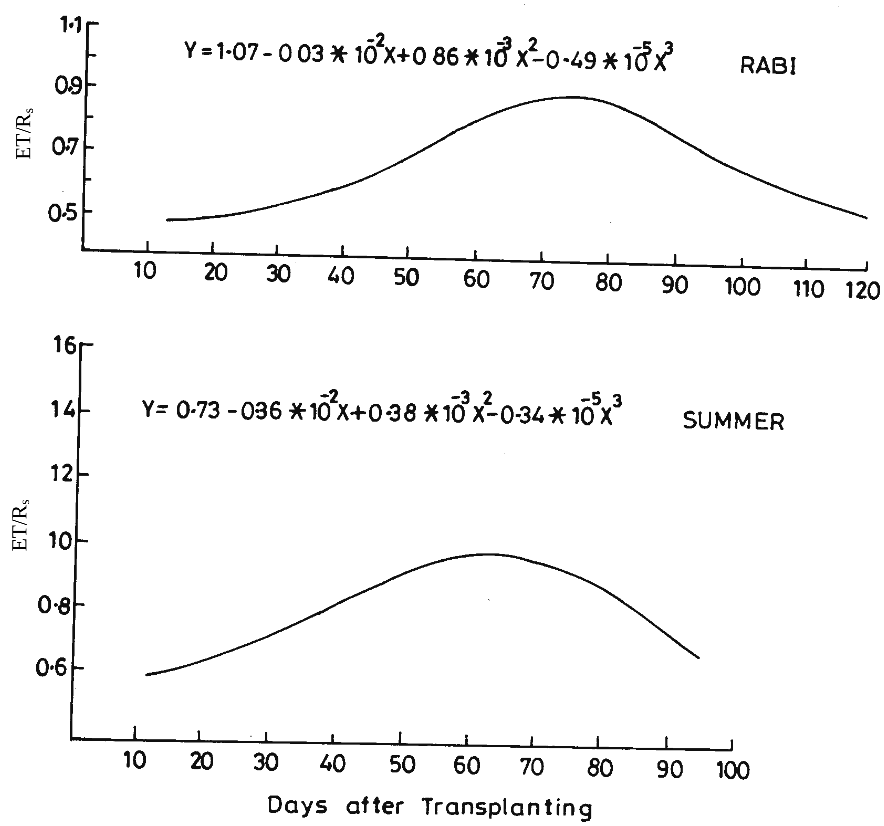

Fig. 3. Relationship between ET/R_s and days after transplanting

countries, ET/EP ratio does not, as a rule, vary much from ET/ PET since EP and PET both represent evaporative power of atmosphere. As such, considering ET/EP as a crop co-efficient Kc, it is seen that it agrees well with the range of 1.05-1.20 crop coefficient given by Hargreaves *et al*. (1985).

Attempt was also made to find out a mathematical relationship between days after planting (x) and ET/EP (y) by fitting a polynomial. In determining the coefficients only those terms which were statistically significant at 5%, were retained. The resulting equations are given below and also depicted in Fig. 2.

Kharif : $y = 0.82 + 0.01\,x - 0.79 \times 10^{-4}\,x^2$ $\quad r = .88$

Rabi : $y = 0.74 + 0.95 \times 10^{-2}\,x + 0.11 \times 10^{-3}x^2 - 0.14 \times 10^{-5}\,x^3$ $\quad r = .97$

Summer : $y = -0.54 + 0.05x + 0.10 \times 10^{-3}\,x^2 - 0.70 \times 10^{-5}x^3$ $\quad r = .95$

It can be seen that except during the kharif when the correlation was slightly less than 0.9, in the remaining two seasons these correlations remained quite high. In other words, from a knowledge of the evaporation, the evapotranspiration from the paddy may easily be estimated form the above equation at any stage of the crop growth.

3.3. *ET/ R_s curve*

The incoming solar radiation (R_s) alongwith the wind and humidity contribute significantly towards the total evaporation of the atmosphere. The ratio ET/ R_s reflects the combined effect of the energy balance components. The measured ET/ R_s values for paddy under two different moisture regimes (seasons) is given in Fig. 3. As persistent cloudiness does not give good association with ET, the same for kharif is not shown. The mean ET/ R_s curve for both seasons have the same general pattern. Maximum ET/ R_s values during rabi was 0.94 and for summer 1.03 and ranged in the two seasons from 0.50 to 1.03.

ET/R_s ratio increases gradually as the vegetation cover develops. The maximum ET/R_s ratio is reached at flowering stage and decreases almost linearly later because of crop senescence. The maximum ET/R_s ratios were generally observed at the time when the plant had reached maximum height. Increased leaf area and concurrent increase in the percentage of the ground shaded by the plant canopy probably explains much of the increase of the ratio during that time. Subsequently, though the plant height remains unaltered, rapid senescence leads to reduced plant evaporation and hence reduced ET/R_s ratio. ET/R_s values for rice were consistently above 0.5 during rabi season and above 0.6 during summer season.

4. Conclusions

The following conclusions could be drawn :

(*i*) Mean consumptive use of water is more during the kharif and rabi seasons than in summer.

(*ii*) The mean ET/EP ratio is highest in kharif season than the other two seasons.

(*iii*) ET/EP reaches its peak during flowering stage in all the three seasons.

(*iv*) The mean weekly evapotranspirative loss during the flowering is nearly 20% of its seasonal value in all three seasons.

(*v*) The ET/R_s ratio increases gradually as the vegetative cover develops and reaches its maximum value at flowering stage.

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