

## Assessment of water requirement of tobacco at Rajamundry (Andhra Pradesh)

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**सार** – इस शोध पत्र में राज मुंदरी में 1979 से 1988 में रबी के मौसम के दौरान बोई गई तंबाकू की किस्मों के लिए जल उपयोग, जल उपयोग क्षमता (डब्ल्यू. यू. ई.) और जल आवश्यकता संतुष्टि सूचकांक (डब्ल्यू. आर. एस. आई.) का अध्ययन किया गया है। तंबाकू की फसल वर्षा जल की राशि, जल उपयोग और जल आवश्यकता संतुष्टि सूचकांक से रैखिक और विशेष रूप से परस्पर संबद्ध होती है। बुआई के समय वर्षा की कुल जल राशि फसल के लिए जल की आवश्यकता को पूरा करने में अपर्याप्त होती है और इस कमी की पूर्ति इससे पहले की खरीफ के मौसम से संग्रहित की गई मृदा की नमी से आंशिक रूप से की गई है। तंबाकू की फसल के पकने की अवस्था में वर्षा की अधिकता पत्तों की उपज और गुणवत्ता को प्रतिकूल रूप से प्रभावित करती है।

फसल की सी. टी. आर. आई. स्पेशल किस्म के लिए 110.0 से 186.6 मि. मी. और जयश्री के लिए 86.8 से 184.0 मि. मी. जल की राशि की खपत अलग-अलग हुई। औसत जल उपयोग क्षमता सी. टी. आर. आई. स्पेशल और जयश्री के लिए क्रमशः 6.1 और 6.4 कि.ग्रा./है./मि. मी. पाई गई है। फसल बढ़वार की अवस्था में जल की अधिकतम राशि 81.2 मि. मी. खपत हुई (अर्थात् 58.7 प्रतिशत) इसके बाद फसल के तैयार होने के समय 36.5 मि. मी. (26.5 प्रतिशत) और फसल के अंतिम रूप से पक कर तैयार होने के दौरान (14.8 प्रतिशत) अपेक्षाकृत कम (20.6 मि. मी.) रही। फसल के पकने की आखिरी अवस्था में औसत Kc मान अधिकतम (0.5) था। जल की आवश्यकता संतुष्टि सूचकांक से फसल की बुआई से पकने के दौरान के ट्रेंड में कमी का पता चलता है और फसल के पकने के आखिरी दौर में जल की आवश्यकता बहुत अधिक होती है और वर्षा के कम होने की वजह से हास दर बढ़ जाती है।

**ABSTRACT.** Water use, Water Use Efficiency (WUE) and Water Requirement Satisfaction Index (WRSI) of tobacco varieties grown during rabi 1979 to 1988 at Rajamundry had been studied. The yield of tobacco was linearly and significantly correlated with amount of rainfall, water use and WRSI. The total amount of rainfall during growing season was inadequate to meet the crop water requirements and these were partially met from stored soil moisture from previous kharif season. The excess rain during ripening stage of tobacco adversely affected the leaf yield and quality.

The amount of water consumed varied between 110.0 to 186.6 mm for CTRI Special, 86.8 to 184.0 mm for Jayashri. The mean WUE was found to be 6.1 and 6.4 kg/ha/mm respectively for CTRI Special and Jayashri. The maximum amount of water consumed was 81.2 mm (*i.e.*, 58.7%) during grand growth stage, followed by 36.5 mm (26.5%) during establishment stage and comparatively less (20.6mm) during maturity stage (14.8%). The average Kc value was maximum (0.5) during grand growth stage. WRSI showed decreasing trend from sowing towards maturity and the rate of decrease was high in grand growth stage due to peak water consumption and less rainfall.

**Key words** – Evapotranspiration, Water use efficiency (WUE) and Water requirement satisfaction index, Tobacco.

### 1. Introduction

Tobacco is non-food commercial crop extensively cultivated in Andhra Pradesh, Karnataka, West Bengal and Bihar States. With rich agro-climatic diversity, India has the unique position of growing all types of tobacco like Flue cured Virginia tobacco, bidi tobacco, cigar and

cheroot tobacco. Rainfall, temperature, relative humidity, wind and sunshine has marked influence on growth, flowering and metabolism of tobacco plant. To maintain turgidity and expansion of its enormous leaf area, tobacco plants needs considerable amount of water. On the other hand, tobacco plants are very sensitive to waterlogged condition of soil.

**TABLE 1**  
**Details of crop variety, duration, date of sowing and harvesting**

Variety	Year	Crop duration (Weeks)	Date of sowing	Date of harvest
CTRI Special	1978	18	10.11.78	7.3.79
	1979	15	1.12.79	10.3.80
	1980	16	19.11.80	5.3.81
	1981	18	11.11.81	9.3.82
	1982	15	16.11.82	22.2.83
Jayashri	1983	17	25.11.83	14.3.84
	1984	16	31.10.84	14.2.85
	1985	16	8.11.85	22.2.86
	1986	14	22.11.86	25.2.87
	1987	12	19.12.87	7.3.88
	1988	16	21.11.88	7.3.89

Tobacco performs well in regions of Andhra Pradesh where the annual rainfall through South-West monsoon is around 800-1000 mm starting from June to October. The crop is mostly grown on conserved soil moisture during rabi season extending from October-November to February-March. Occasionally, the rain during North-East monsoon becomes booster to this crop yield. The crop requires above average bright sunshine hours, low evaporation, high relative humidity, sustained soil moisture in black soils.

The irrigation requirement of tobacco crop often depends on the distribution of rainfall, soil moisture status, stage of crop growth and evapotranspiration demand of atmosphere. When it is grown as a rain fed crop, it requires at least 50 cm of well distributed rainfall throughout the growing season. It requires 100-115 cm of annual precipitation for successful production. Rainfall is considered undesirable at the time of maturing of the crop as gums and resins on the leaf get washed. Tobacco suffers severe injury from strong winds and hail. The total water requirement of tobacco under Rajamundry conditions as calculated by climatological data is about 50cm (Sriramamuthy and Gopinath, 1965). A major part of this is supplied by stored soil moisture and the remaining quantity of 10 to 15 cm is to be met partly by rain and partly by irrigation. In the northern light soils of Andhra Pradesh, altogether six to seven irrigations are needed for flue cured tobacco, starting three weeks after planting, at 18 mm each for first two irrigations, 25 mm

each for next two irrigations and 37 mm at topping stage and 25 mm each for the last two irrigations. Considering these facts, the present study was conducted with the objective of finding out the water requirement at different growth stages, water requirement satisfaction index from sowing to harvesting at weekly intervals in tobacco varieties in Rajamundry.

## 2. Data and methodology

The evapotranspiration (ET) data of tobacco crop grown in rabi season from 1978-1988 collected from gravimetric lysimeters at Rajamundry situated in East Godavari district of Andhra Pradesh (location 17° 0' N, 81° 46' E, 111 m.a.s.l.) have been used. Rajamundry is located in Krishna Godavari agroclimatic zone with an annual rainfall of 1131.2 mm, mean maximum temperature of 33.1 °C and mean minimum temperature of 22.1 °C. The soils at Rajamundry are clayey in nature with a water holding capacity of 220 mm. The details of experiment, variety, crop duration, dates of sowing and harvest are furnished in Table 1. The two varieties of tobacco, viz., CTRI Special grown from 1978-1982 and Jayashri grown from 1983-88 have been studied.

The weekly total values of Lysimetric ET (ETL), weekly total rainfall (mm), mean evaporation (mm), crop yield and other agro meteorological data were obtained from the published ET report from Agrimet Division, IMD, Pune. Potential evapotranspiration were computed

**TABLE 2**  
**Lysimetric ET(ETL) and Potential Evapotranspiration, rainfall and yield of tobacco in Rajamundry**

Variety	Year	Crop duration (Weeks)	Lysimetric ET (mm)	Weekly ETL (mm)	PET (mm)	Rainfall (mm)	Evaporation (mm)	Yield (kg/ha)	WUE (kg/ha/mm)
CTRI Special	1978	18	186.6	10.4	426.5	126.1	601.4	-	-
	1979	15	110.0	7.3	377.0	6.8	468.5	691	6.28
	1980	16	135.9	8.5	391.5	23.6	550.4	880	6.48
	1981	18	137.5	7.6	458.7	0.0	566.5	809	5.88
	1982	15	112.6	7.5	329.4	2.0	399.7	927	8.23
	<b>Mean</b>	<b>16.4</b>	<b>136.5</b>	<b>8.3</b>	<b>396.6</b>	<b>31.7</b>	<b>517.3</b>	<b>826.8</b>	<b>6.06</b>
Jayashri	1983	17	184.0	10.8	392.8	71.4	501.4	1168	6.35
	1984	16	182.8	11.4	382.5	67.9	508.7	960	5.25
	1985	16	147.2	9.2	366.2	38.0	449.5	1105	7.51
	1986	14	147.9	10.6	339.1	40.8	432.4	1050	7.10
	1987	12	86.8	7.2	-	1.8	332.0	427	4.92
	1988	16	88.5	5.5	-	0.0	503.7	620	7.01
	<b>Mean</b>	<b>15.2</b>	<b>139.5</b>	<b>9.1</b>	<b>370.2</b>	<b>36.7</b>	<b>454.6</b>	<b>888.3</b>	<b>6.40</b>

- Data not available

on weekly basis using the CROPWAT model. From the observed data seasonal total rainfall, seasonal ETL and mean weekly evapotranspiration were worked out. Water use efficiency (WUE) was calculated using the following formulae.

$$\text{Water use efficiency (WUE) (kg ha}^{-1} \text{ mm}^{-1}) = \frac{\text{Yield (kg ha}^{-1})}{\text{Seasonal total ET (mm)}} \quad (1)$$

Growth phasewise water use (ETL) of tobacco was computed from weekly ETL by following duration of each of phenophases, viz., establishment (0-5 weeks after sowing) (WAS), grand growth (6-12 WAS) and maturity (13-16 WAS) of the crop. The percentage of water used in each phenophase was also worked out and presented. The value of crop coefficient (K<sub>c</sub>) has been estimated for different phenophases of the crop using the following relationship (Dorrenbos and Pruitt, 1975)

$$K_c = \text{ETL} / \text{PET} \quad (2)$$

The amount of irrigation was added to the amount of rainfall and total of rainfall and irrigation was taken as inputs for computing Water Requirement Satisfaction Index (WRSI). The water balance parameters, viz., soil moisture storage, water surplus; water deficit and WRSI were computed as per the method of Frere and Popov (1979).

$$\text{WRSI}_i = [\text{WRSI}_{i-1} + (\text{ASM}/\text{TWR})] * 100 \quad (3)$$

Where,

WRSI<sub>i</sub> = Water requirement satisfaction index for i<sup>th</sup> week

WRSI<sub>i-1</sub> = Water requirement satisfaction index for the previous week

ASM = Available soil moisture during the week

TWR = Total water requirement of the entire crop season (ET)

After examining normal yield of tobacco and local conditions at Rajamundry, the WRSI categories as good, average, poor and failure are made.

WRSI (%)	Description
95-100	Good
80-94	Average
50-79	Poor
< 50	Failure

Correlation between tobacco yield and total weekly rainfall, water use of tobacco, water requirement satisfaction index were studied and regression equations were developed and discussed in this paper.

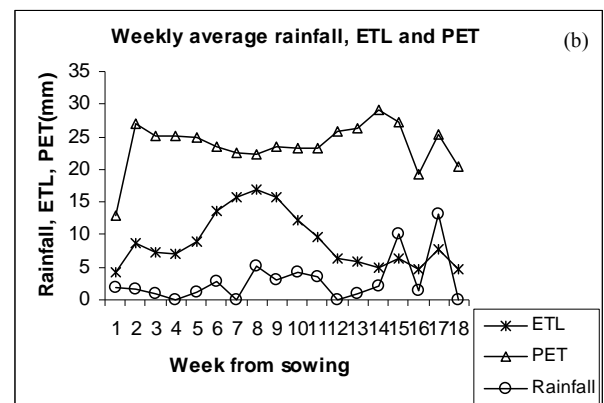
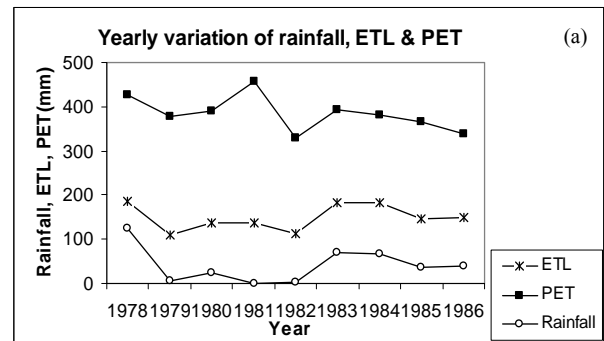
### 3. Result and discussions

#### 3.1. Weather during crop growth period and effect of weather on tobacco

Rainfall received along with other agrometeorological parameters, and crop yield of tobacco in different years at Rajamundry are shown in Table 2. Rainfall during the tobacco growing season showed variation across the years. The data of rainfall, actual evapotranspiration reveals that the rainfall during growing season is less than actual evapotranspiration which indicates the rest of the water requirement of tobacco is met from residual soil moisture from monsoon rain. During 1978, there is excess rainfall of 77.3 mm rainfall during 7<sup>th</sup> standard week. This would have resulted in damage to the leaves of tobacco because the rain during maturity of leaves could have resulted in washing of the gums from the leaf surface resulting in poor curing. The actual rainfall in most of the years during establishment and maturity stages were higher than normal rainfall. On the other hand, actual rainfall during grand growth stage is found much higher than normal rainfall which is beneficial to the crop.

#### 3.2. Relationship between rainfall, consumptive use of water (ETL) with yield and water use efficiency (WUE)

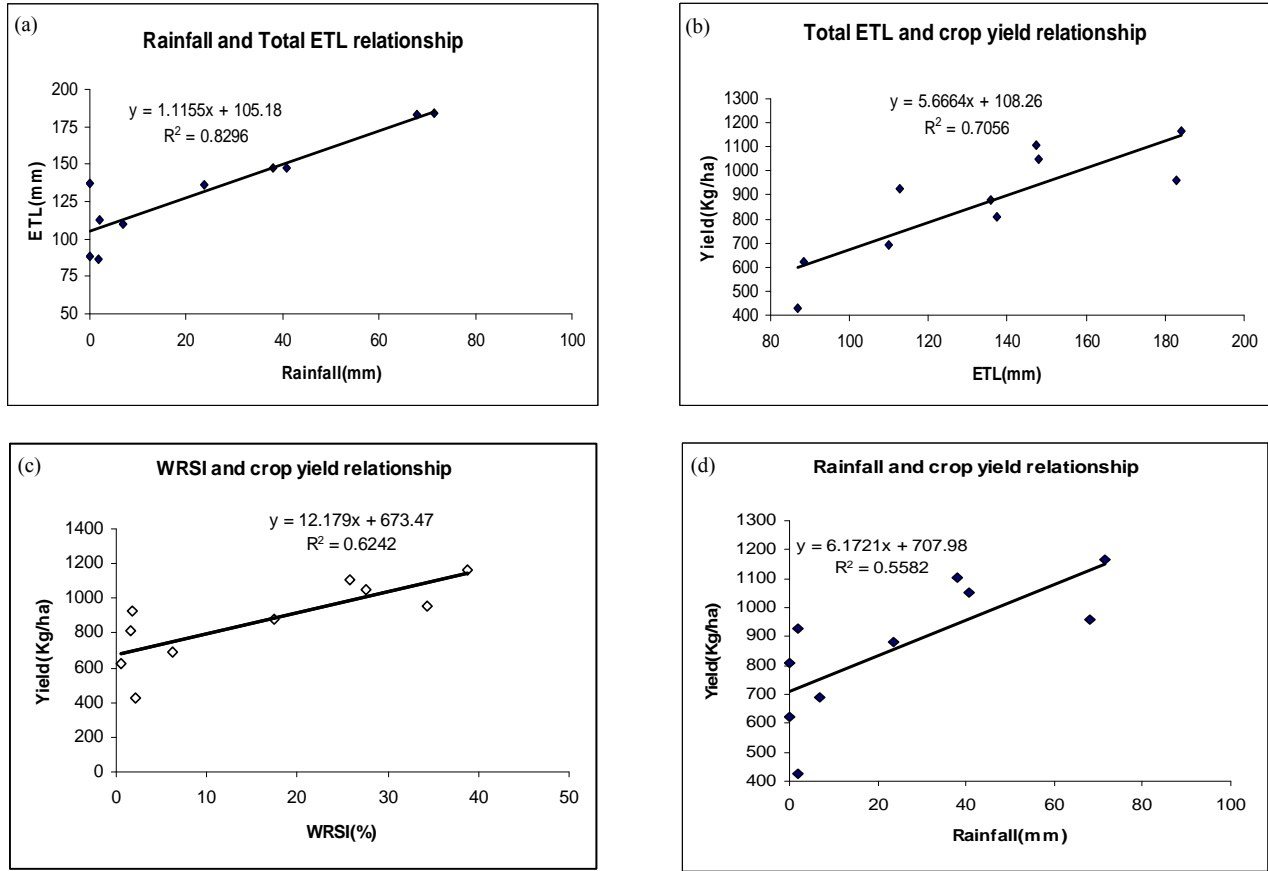
The growth duration of tobacco variety CRTI Special varied between 15 and 18 weeks and Jayashri varied between 12 and 16 weeks. The average yield was 826.8 kg/ha, 888.3 kg/ha respectively for CRTI Special and Jayashri. The amount of water consumed by CRTI Special in different years varied between 110.0 to 186.6 mm and by Jayashri were 86.8 to 184.0 mm. On an average, both the crop varieties consumed nearly same quantum of water about 140 mm. The weekly average water requirement was 8.3 mm/week for CRTI Special and 9.1 mm/week for Jayashri. The actual rainfall received in different seasons varied from 0 mm to 126.1 mm and PET varied from 329.4 to 426.5 mm. The water use efficiency (WUE) varied between 5.88 and 8.23 kg/ha/mm for CRTI Special, 4.92 and 7.51 kg/ha/mm for Jayashri. The average WUE was found to be 6.1 and 6.4 kg/ha/mm respectively for CRTI Special and Jayashri. Jayashri has higher WUE due to higher yield as compared to CRTI Special and water use remained nearly same. It is seen that WUE does not depend only on the total amount of water consumed by the



**Figs. 1(a&b).** (a) Total seasonal rainfall, ETL and PET during crop growing season and (b) Weekly average rainfall, ETL and PET

crop but also indicates the importance of its distribution during the various growth stages.

The yearly variations as well as weekly average rainfall, Lysimetric evapotranspiration (ETL) and potential evapotranspiration (PET) are shown in Figs. 1(a&b). In all the years, ETL and rainfall were much below the potential evapotranspiration. During 1987 and 1988 rainfall was deficit during crop growing period and in the absence of adequate irrigation the yields were low. Though the rainfalls were low during 1985 and 1986, but availability of high stored soil moisture might have contributed to high yields of tobacco. Similarly the weekly average rainfall and ETL is much below the potential evapotranspiration and also rainfall during establishment and grand growth stages are lesser than ETL. Whereas during maturity in 15<sup>th</sup> and 17<sup>th</sup> weeks after sowing the amount of rainfall is higher than ETL. The rainfall during maturity and harvesting stages of crop has adversely affected the yield and quality of crops. It is observed from Fig. 2(a) that ETL and rainfall are linearly



**Figs. 2(a-d).** Relationship between (a) total seasonal rainfall and total ETL, (b) total ETL and yield, (c) WRSI during last week and yield and (d) rainfall and yield

correlated ( $r^2 = 0.83$ ). The regression equation is as follows:

$$y = 1.1155x + 105.18 \tag{4}$$

Where  $x$  = rainfall (mm).

Figs. 2(b-d) shows that yield is linearly correlated to total ETL, WRSI and rainfall and the type of relationship between the total ETL, WRSI and rainfall is as follows:

Total ETL and yield

$$y = 5.6664x + 108.26 \tag{5}$$

$$r^2 = 0.71$$

Where,  $x$  = total ETL (mm)

WRSI and yield

$$y = 12.179x + 673.47 \tag{6}$$

$$r^2 = 0.62$$

Where  $x$  = WRSI (%)

Rainfall and yield

$$y = 6.1721x + 707.98 \tag{7}$$

$$r^2 = 0.56$$

Where  $x$  = rainfall (mm)

Similar positive correlation was observed between WRSI and grain yield in maize in Andhra Pradesh by Jayashree *et al.* (2008)

### 3.3. Phasewise water requirement and crop coefficient

Phasewise water use by tobacco at Rajamundry during different years are furnished in Table 3. Considerable variation is noted in water use which is due to dissimilar weather experienced during different crop season and large year to year variations are also seen at different growth stages like establishment (27.2 to

**TABLE 3**  
**Phase wise Lysimetric ET and crop coefficient of tobacco in Rajamundry**

Year	Phase wise ETL			
	Establishment	Grand growth	Maturity	Seasonal
1978	36.6(19.6)	78.3(42.0)	71.7(38.4)	186.6
1979	33.3(30.3)	62.3(56.6)	14.4(13.1)	110
1980	30.2(22.2)	93.2(68.6)	12.5(9.2)	135.9
1981	39(28.4)	79.2(57.6)	19.3(14.0)	137.5
1982	33.5(29.8)	70.2(62.3)	8.9(7.9)	112.6
1983	48.2(26.2)	116.5(63.3)	19.3(10.5)	184
1984	57.6(31.5)	109.6(60.0)	15.6(8.5)	182.8
1985	41.9(28.5)	82.4(56.0)	22.9(15.5)	147.2
1986	25.8(17.4)	101.1(68.4)	21(14.2)	147.9
1987	27.2(31.3)	48.3(55.7)	11.3(13.0)	86.8
1988	28.7(32.4)	51.7(57.9)	8.7(9.7)	88.5
Mean	36.5(26.5)	81.2(58.7)	20.6(14.8)	138.2
	Crop Coefficient			
	Establishment	Grand growth	Maturity	
1978	0.3	0.5	0.6	
1979	0.3	0.4	0.1	
1980	0.2	0.5	0.1	
1981	0.3	0.5	0.1	
1982	0.3	0.5	0.1	
1983	0.4	0.7	0.2	
1984	0.4	0.5	0.2	
1985	0.4	0.5	0.2	
1986	0.3	0.7	0.2	
Mean	0.3	0.5	0.2	

Values in parenthesis are percentage of cumulative ETL.

57.6 mm) and grand growth (48.3 to 116.5 mm) and maturity (8.7 to 71.7 mm). In this table it is seen that maximum amount of water consumed was 81.2 mm (*i.e.*, 58.7%) during grand growth stage, followed by 36.5mm (26.5%) during establishment stage and water consumed was less 20.6 mm (14.8%) during maturity stage. The average weekly ET were found to be varied over years and it was found lowest in 1988 (5.5 mm/week) and highest in 1984 (11.4 mm/week).

The correlation analysis between water consumed (ETL) during all three growth stages, *viz.*, establishment, grand growth and maturity and yield were done.

The relationship between water used during establishment stage and yield was,

$$y = 11.711x + 435.8 \quad (8)$$

$$r^2 = 0.2669$$

Where,

$x$  = amount of water consumed during establishment stage

The relationship between water used during grand growth stage and yield was,

$$y = 8.3081x + 187.42 \quad (9)$$

$$r^2 = 0.7244$$

Where,

$x$  = amount of water consumed during grand growth stage

The relationship between water used during maturity stage and yield was,

$$y = 30.103x + 400.71 \quad (10)$$

$$r^2 = 0.4377$$

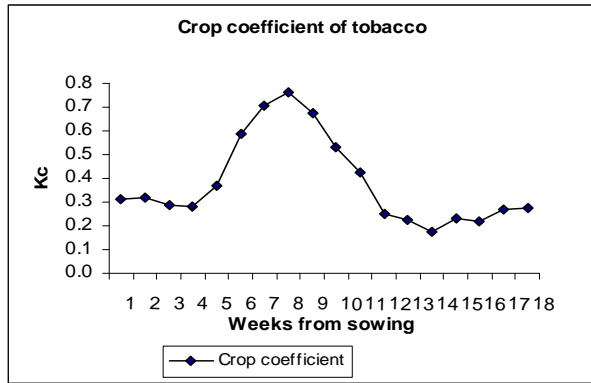


Fig. 3. Crop coefficient during different weeks

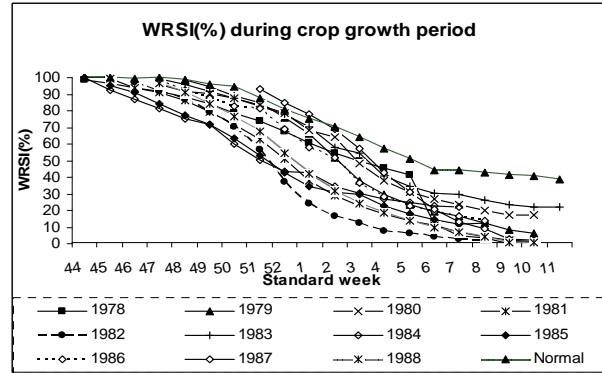


Fig. 5. WRSI(%) during crop growth period

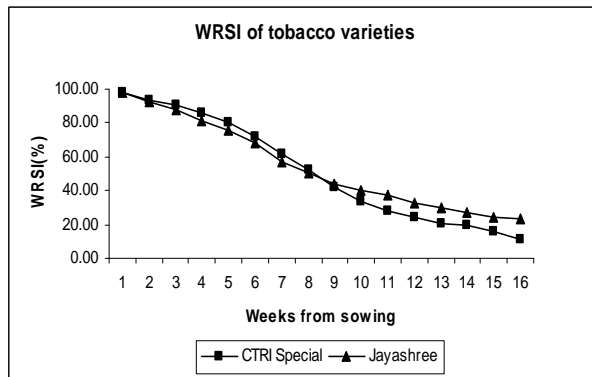


Fig. 4. WRSI of tobacco varieties during different weeks

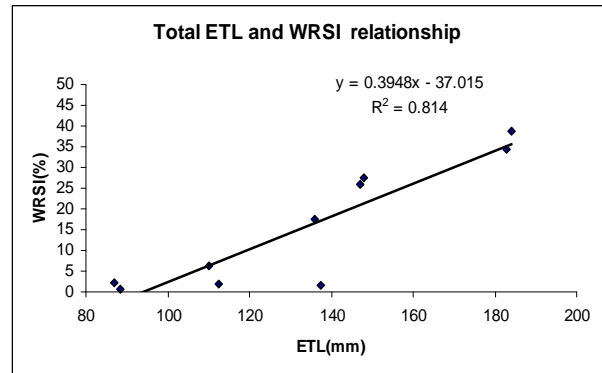


Fig. 6. Relationship between total ETL and WRSI

Where,

$x$  = amount of water consumed during maturity stage

However, correlation analysis using water consumed during grand growth stage (Eqn. 10) revealed that the amount of ETL during grand growth stage would be utilizable to predict yield with fairly good accuracy.

The values of phase wise and week wise  $K_c$  during the growing season are shown in Table 3 and illustrated in Fig. 3. It is observed that the  $K_c$  gradually increases from establishment stage as plant development progresses, attaining the highest value of 0.5 during grand growth stage. It means the atmospheric demand for water is high during grand growth stage, when the crop is actively growing. If the crop suffers from water stress during this critical growth period, the loss of water at its optimum rate will be affected, and in turn, adversely affect the yield considerably. Thereafter  $K_c$  decreases gradually and attains lowest at maturity (0.2). The effect of plant senescence is also been by gradual decline in  $K_c$  values

during the maturity phase. The trend observed in  $K_c$  values of tobacco during different stages of growth were compared with those given by Doorenboss and Kasam (1979), which agreed fairly well. The  $K_c$  was found to be varied over years, *i.e.*, 0.2 to 0.4 during establishment stage, 0.4 to 0.7 during grand growth stage and 0.1 to 0.6 during maturity stage.

### 3.4. WRSI during crop growth period of tobacco

The rainfall received during most of the weeks of tobacco growth is less than actual evapotranspiration. The frequency table of WRSI categories at Table 4 indicates that the frequencies of failure are highest followed by average and medium in different years. During 1984, the highest amount water deficit was noticed in establishment stage while compared to the remaining years. WRSI of the two varieties depicted in Fig. 4 showed that there was not much difference in WRSI during different weeks of crop growth. The WRSI indicates the extent to which the water demand of the crop was met during the crop growth period. It was noticed that the WRSI is linearly decreasing with the advancement of crop growth and the rate of decrease is much high during grand growth stage (Fig. 5).

**TABLE 4**  
**Frequency of Water Requirement Satisfaction Index of tobacco at Rajamundry**

Year	Frequency of WRSI category(weeks)				Total
	Good	Average	Poor	Failure	
1978	3	3	5	7	18
1979	1	3	3	8	15
1980	1	4	3	8	16
1981	1	3	4	10	18
1982	1	2	3	9	15
1983	2	3	4	8	17
1984	2	2	4	8	16
1985	1	2	4	9	16
1986	1	4	3	6	14
1987	0	2	3	7	12
1988	1	2	3	10	16
Mean	1	3	4	8	16

This may be attributed due to increasing water use with less rainfall over the crop growth period. At the end of growing period at maturity the WRSI results are not encouraging since the index comes under failure WRSI (< 50%) category as defined by FAO in all the years. During 1983 and 1984, the WRSI value at the end of the growing season is more than 30% and in all the remaining years the same was less than 30%. Fig. 6 showed that ETL and WRSI are linearly correlated ( $r^2 = 0.81$ ). The regression equation is as follows:

$$y = 0.3948x - 37.015 \quad (11)$$

Where  $x$  = Lysimetric evapotranspiration (mm).

Despite the tobacco cultivation in Andhra Pradesh is possible by utilization of residual soil moisture, occasional rainfall in north east monsoon and rainfall due to cyclonic storms.

#### 4. Conclusions

The following conclusions are drawn from the study.

- (i) The yield of tobacco is positively correlated with rainfall received during crop growth period.
- (ii) The mean water use of tobacco variety CTRI Special was found to be about 137 mm and 140 mm for Jayashri at Rajamundry. Correlation analysis revealed that grand growth stage is the most important stage and the amount of water used during this stage can be used to predict tobacco yield with fairly good accuracy ( $r^2 = 0.72$ ).

(iii) The average WUE was found to be 6.1 and 6.4 Kg/ha/mm respectively for CTRI Special and Jayashri.

(iv) Crop coefficient ( $K_c$ ) values started increasing sharply from 4 weeks after sowing and attained peak (0.8) at 8 weeks after sowing which corresponds grand growth stage and started declining up to 12 weeks after sowing.

(v) WRSI decreases linearly from the first week of sowing as the crop growth advances and the rate of decrease is much high in grand growth stage corresponding to peak water demand stage. WRSI is positively correlated with water use and tobacco yield. Mustard or gram can be grown as alternate crops to tobacco with same amount of water.

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