

## Leaf area index, evapotranspiration and dry bio-mass of maize (*Zea mays* L.)

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सार—1989 और 1990 के लिए फसल मौसम आंकड़ों पर आधारित पर्ण क्षेत्र सूचकांक (एल. ए. आई.), जीव मात्रा, जल प्रयोग क्षमता, मृदा वाष्पन, विभव और वास्तविक वनस्पति वाष्पोत्सर्जन का निर्धारण किया गया है। उपर्युक्त फसल विशेष कारकों के मध्य उपरिमुद्रा प्रोफाइल में नमी सहित कुछ सह संबंधों का भी पता लगाया गया। यह विश्लेषण दर्शाता है कि फसल के मौसम के दौरान कुल वर्षा मक्का की फसल पर अधिक प्रभाव नहीं डालती है। जल प्रयोग क्षमता वायुमंडलीय आवश्यकता से लगभग स्वतंत्र है। मृदा से वास्तविक और विभव वनस्पति वाष्पोत्सर्जन और वाष्पन का आकलन साधारण निर्देश से किया जा सकता है।

**ABSTRACT.** Based on the crop season data for the years 1989 and 1990, LAI, bio-mass, water use efficiency, soil evaporation, potential and actual plant transpiration have been determined for maize. The ET/EP ratio has been correlated with LAI and dry bio-mass. Correlations were also determined between some of the above crop characteristic factors as also with moisture in top soil profile. The analysis indicated that total rainfall during crop season does not have large bearing on the maize yield. The water use efficiency appears to be nearly independent of atmospheric demand. Actual and potential plant transpirations and the evaporation from the soil could be computed from a simple model.

**Key words** — Soil evaporation, Plant transpiration, Leaf area index.

### 1. Introduction

In locations where lysimeters are not available the evapotranspiration (ET) is found indirectly through evaporation (EP). Use of evaporation measurements for such purposes is considered unsatisfactory as ET is influenced by the development stage of the crop. ET is also affected by wetness of the ground surface which often occurs during rainy season. As the leaf area index (LAI) increases the importance of EP from open surface decreases in relation to ET (Khurana and McLaren 1982) studied influence of leaf area and light interception on potato growth. A knowledge of EP, ET and LAI is useful in irrigation scheduling of field crops. Relationship between LAI and ET of Taro, a wetland plant, was studied by Shih and Snyder (1985). Singh and Rama (1989) determined relationship between EP, ET and LAI while examining influence of water deficit on ET for chickpea.

In the present study an attempt has been made to determine relationship between LAI, ET and bio-mass for maize (*Zeamays* L.) crop. Variation of LAI with crop development and seasonal variations of EP was also determined and discussed.

### 2. Data

The study utilises data for maize (var., Ganga Safed-2) during the crop seasons 1989 and 1990 at Anand

(Gujarat). The soil around Anand is mostly sandy loam with field capacity 17%, bulk density 1.5 g/cm<sup>3</sup> and permanent wilting point 5%. The ET was measured with gravimetric lysimeter located in the crop field. The EP values refer to standard US open pan evaporimeter. From the daily values, weekly values of ET and EP have been computed. After germination, the bio-mass was weighed by dry oven method every week. The LAI values were obtained by using leaf area meter.

For 1989, LAI and bio-mass data were available only from 7th to 11th week of sowing, i.e., during the period of cob occurrence. In both years the crop duration (sowing to harvest) was 93 days and the last two days were omitted in the analysis.

### 3. Cultural practices

Maize was sown by dibbling method on 11 July in 1989 and 7 July in 1990. The spacing between plants and between rows were 20 and 60 cm respectively in both the years. During both the years, crop was given N,P,K as 100 : 50 : 0 kg/ha. Inter-cultural operations were carried out 4 times in 1989 and 2 times in 1990 during last half of July to remove weeds.

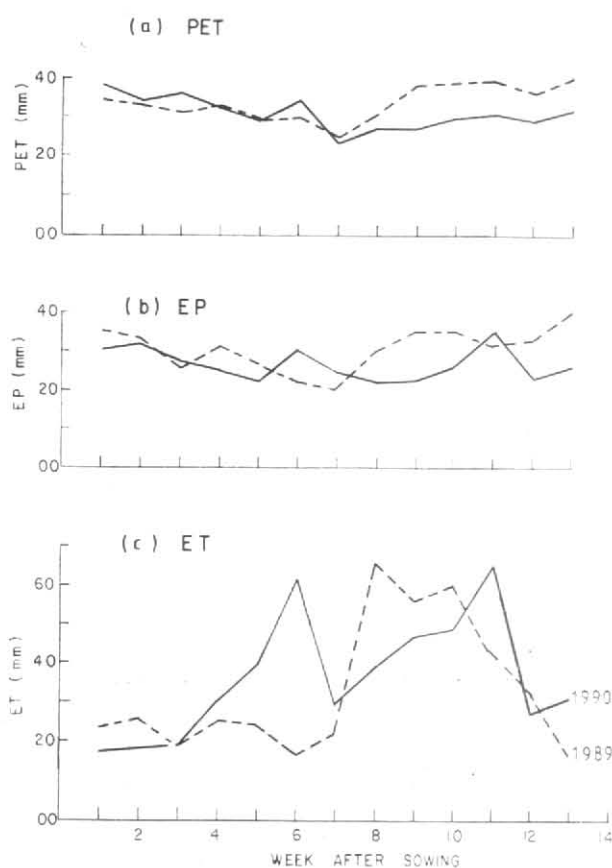


Fig. 1. Weekly distribution of ET, EP and PET

#### 4. Results and discussion

##### 4.1. Crop characteristics

Large differences in crop characteristics between the years 1989 and 1990 are due to differences in the rainfall in the respective crop seasons. As against 509 mm of rainfall in 1989, the succeeding year recorded 998 mm of rainfall (Table 1). The water use by maize was about 440 mm in 1989 and 380 mm in 1990. Incidentally EP was 22% more during the year 1989 compared to 1990.

Final dry matter (fodder) was nearly 25% more in 1990 whereas the grain yield was 10% less compared to 1989. The dry bio-mass obtained was 5565 kg/ha in 1989 and 7482 kg/ha in 1990. The water use efficiency (WUE) in both years was practically identical, in spite of higher rainfall in 1990. Bhan *et al.* (1990), observed that the WUE decreases in sorghum with increased irrigation at the cost of dry matter production.

##### 4.2. ET, EP variations

The weekly values of ET, EP and PET are shown in Fig. 1 for both the years. The PET values were

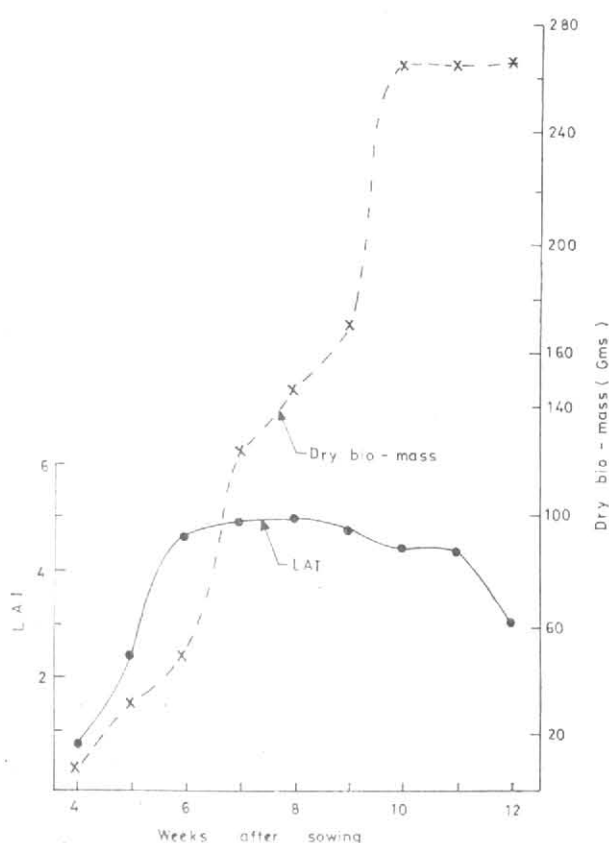


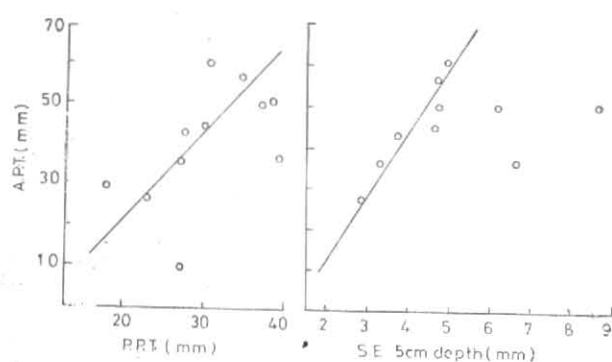
Fig. 2. Weekly variation in LAI and dry bio-mass

computed as per Monteith's modified equation. The origin of the time axis is from the date of sowing.

Large variations in weather parameters were observed in the years 1989 and 1990. Increase in ET values is seen from 8th to 10th week after sowing during the year 1989 and were higher than the values in 1990 for the corresponding period. In 1990 the ET values registered a rise till 6th week after sowing, the peak coinciding with first occurrence of tasseling. Subsequently it declined but attained another peak towards the end of the crop season in the 12th week. This high was due to horizontal water flow from the adjoining field by irrigation and also by a sudden spurt in atmospheric demand (as seen in rise in EP).

During rainy season, the sky was almost cloudy due to persistent cloudiness and as a result EP also decreased immediately following the rainfall, but not ET. The higher values of ET as compared to EP in 1990 can thus be reconciled.

The EP values may also be considered as the evaporative power of the atmosphere. In 1989, EP was more than 20.0 mm from 7th week onward till harvest and were generally higher than those for the succeeding year during the corresponding period. The same was generally true in case of PET.



(Fig. 3)

(Fig. 4)

Relationship between: (Fig. 3) actual and potential plant transpiration, and (Fig. 4) soil evaporation and actual plant transpiration [In Fig. 3 PPT may be read as PTp]

TABLE 1  
Seasonal crop characteristics

Parameters	1989	1990
Rainfall (mm)	508.5	997.9
Evapotranspiration (mm)	427.7	373.9
Evaporation (mm)	411.7	339.3
Potential evapotranspiration (mm)	436.1	404.1
Fodder yield (kg/ha)	5444	6853
Grain yield (kg/ha)	4222	3800
Water use efficiency (kg/ha/cm) (WUE)	98.7	161.6

TABLE 2  
Correlation between LAI dry bio-mass and ET/EP ratio

Variable	Dry bio-mass	ET/EP
LAI	0.46	0.68
$(LAI)^{\frac{1}{2}}$	0.50	0.72
$(LAI)^{\frac{3}{2}}$	0.42	0.65
$\ln(LAI)$	0.52	0.74

Nearly 98% of the atmospheric demand, as given by PET, was met by ET in 1989 and 92% in 1990.

#### 4.3. LAI and dry bio-mass

Weekly variations of LAI and dry bio-mass for 1990 is shown in Fig.2.

After germination LAI is seen to increase rather slowly initially, followed by a period of rapid enhancement of the canopy cover. This LAI attained a peak of 5 in the 6th week after sowing when canopy was fully developed and remained same nearly for the next 3/4 weeks. At this stage, the rate of loss of lower leaves in the crop probably equalled the rate of production of new leaves. The dry matter production increased in association with increase in LAI and continued to increase at a faster rate even after the LAI had reached its maximum. The maximum dry mass was recorded in 10th week when silk occurrence was nearing completion.

In 1989, the rate of spread of leaf canopy was slow and foliage attained a maximum value in 9th week after sowing. The LAI values during 7th to 11th weeks for 1989 were found to be less by 0.7 in 1989, confirming slow development of plant canopy. The average weekly ET for the 7-11th week in 1989 and 1990 were 49.4 and 43.9 mm respectively. The higher values of ET in 1989 may be the result of inability of small crop canopy in providing adequate soil shading whenever the soil surface was wet. Analysis of dry matter production for the period (*i.e.*, 7-11th week) in 1989 with the corresponding figures in 1990 showed that in 1990 the dry matter yield was nearly double that of 1989.

Correlations worked out between LAI and dry mass for 1990 is given for various LAI transformation (*i.e.*, linear, square root, cubic root and natural logarithm) in Table 2.

The dry matter production, though a function of LAI is not entirely dependent on the latter. Spread of leaf canopy after sowing may not necessarily lead to greater drymass production. When the lowest leaves receive more radiation for photosynthesis, they are unable to balance respiration. At this stage, even though foliage is more, production is less. Perhaps, for this reason the correlation between dry matter and LAI in the present case, though significant, was not large.

Relation between LAI and ET/EP ratio for 1990, is also given in Table 2.

As in case of dry matter, the highest correlation was for log transformation. The following equation describe the relationship between the two :

$$ET/EP = 0.35 \ln LAI + 1.33 \quad (1)$$

$(r = 0.74)$

It is obvious that the relationship between LAI and ET/EP is non-linear. This non-linearity could be due to less competition for energy per unit area in maize crop in nearly all stages of growth (*cf.* Ritchie and Burnett 1968).

Attempt was also made to determine relationship between weekly ET/EP ratio and dry matter production for 1990. The correlation was, however, found very low and statistically insignificant.

#### 4.4. Estimates of soil evaporation and plant transpiration

Evaporation from soil beneath a crop canopy is rather difficult to measure because of boundary layer moisture convergence, decreased wind flux, plant shading etc. According to Phillip's (1957) model which was later revised by Ritchie (1972), the soil evaporation occurs in two manners, viz., at constant rate stage and at falling rate stage. In the constant rate stage the soil is assumed sufficiently wet while in the second category, the soil moisture is assumed independent of PET. During the kharif season, the soil is generally moist, wetted as it is by frequent monsoon showers. In this study, the first category of Ritchie's (1972) model has been used.

The weekly soil evaporation  $E_s$  was calculated for all available LAI values as below :

$$E_s = PET (1 - 0.43 LAI) \quad (2)$$

for LAI < 1.0

$$= PET / 1.1 e^{-0.4 LAI} \quad (3)$$

for LAI  $\geq$  1.0

The potential plant transpiration  $PT_p$  was calculated using the following relationship :

$$PT_p = PET (1 - e^{-LAI}) \quad (4)$$

when LAI  $\leq$  3.0

$$PT_p = PET \quad (5)$$

when LAI > 3.0

Whenever  $PT_p + E_s > PET$ , then

$$PT_p = PET - E_s \quad (6)$$

Actual plant transpiration,  $PT_a$  was calculated as the difference between evapotranspiration, obtained from lysimeter and soil evaporation as below :

$$PT_a = ET - E_s \quad (7)$$

The plot of potential ( $PT_p$ ) and actual plant transpiration ( $PT_a$ ) calculated from the above method are given in Fig. 3. As may be seen in Eqns. (6) and (7), the same quantity, i.e., soil evaporation is subtracted from potential evapotranspiration and actual evapotranspiration. Since PET is generally more than ET, the actual plant transpiration must be less than the potential plant transpiration. This was confirmed from the results in this study. The correlation between the two was 0.52.

Fig.4 contains distribution of  $PT_a$  against the soil moisture at 5 cm depth. The linear relationship between the two is obvious. The actual transpiration depends not only on the amount of moisture available in the top soil layer but other factors like drying power of the atmosphere, capillary action of the soil etc. It was for these reasons, the correlation between the actual plant transpiration and soil moisture, though positive and significant, is not large, i.e., 0.35.

The actual plant transpiration was found to have 0.56 correlation with log transformation of dry matter. All these correlations suggest that the model assumed in computing the parameters are physically and physiologically sound and applicable to crops in India.

#### 5. Conclusions

The following conclusions could be drawn from the studies :

(i) The water use by the maize plant is not much dependent on the total rainfall during crop season.

(ii) The leaf area index does not appear to bear significant relationship with dry bio-mass production.

(iii) Early development of maize crop canopy may not necessarily lead to good yield.

(iv) The ET/EP ratio is significantly correlated with LAI.

(v) The water use efficiency for maize is about 10 kg/ha/cm.

(vi) The actual plant transpiration is significantly related to the evaporation from the top soil.

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