STUDY OF EVAPOTRANSPIRATION OF WHEAT CROP IN VARYING SOIL MOISTURE CONDITIONS

A thesis submitted to the
MAHATMA PHULE AGRICULTURAL UNIVERSITY
Rahuri-413 722 (Maharashtra)

in partial fulfilment of the
requirements for the
Degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

AGRICULTURAL METEOROLOGY

by

JAYAWANT DADAJI JADHAV

B.Sc. (Agri.) First Class

CENTRE OF ADVANCED STUDIES IN AGRICULTURAL
METEOROLOGY
COLLEGE OF AGRICULTURE
PUNE - 411 005 (MAHARASHTRA

1991

Dedicated to

the loving memory

of my father

Late Mr. Dadaji K. Patil

... Jayawant

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Approved by the advisory committee

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1991

CANDIDATE'S DECLARATION

I hereby declare that the thesis entitled, "Study of Evapotranspiration of Wheat Crop in Varying Soil Moisture Conditions," or part thereof, has not been submitted by me or any other person to any other University or Institute for a Degree or Diploma.

Place : Pune
Date : 28/6/91

J.D. Jadhav

Prof. M.C. Varshneya,
Chairman and Research Guide,
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C E R T I F I C A T E

This is to certify that the thesis entitled, "Study of Evapotranspiration of Wheat Crop in Varying Soil Moisture Conditions," submitted to the Faculty of Agriculture, Post Graduate Institute, Mahatma Phule Agricultural University, Rahuri 413 722, District: Ahmednagar, Maharashtra State, in partial fulfillment of the requirement for the degree of MASTER OF SCIENCE (AGRICULTURE) In AGRICULTURAL METEOROLOGY, embodies the results of a piece of bona fide research work carried out by Shri. J.D. Jadhav, under my guidance and supervision and that no part of the thesis has been submitted for any other degree or publication.

The assistance and the help received during the course of this investigation and sources of literature referred to have been acknowledged.

28/6/97

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Date :

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CERTIFICATE

This is to certify that the thesis entitled, "Study of Evapotranspiration of Wheat Crop in Varying Soil Moisture Conditions," submitted to the faculty of Agriculture, Mahatma Phule Agricultural University, Rahuri, District: Ahmednagar, Maharashtra State, India in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (AGRICULTURE) in AGRICULTURAL METEOROLOGY, embodies the results of a piece of bona fide research carried out by Shri. J.D. Jadhav, under the guidance and supervision of Prof. M.C. Varshneya, Head,Center of Advanced Studies in Agricultural Meteorology, College of Agriculture, Pune, Maharashtra State, India, and that no part of the thesis has been submitted for any other degree or publication.

Place : Pune
Date : 16 JUL 1991

(D.S. Ajri)

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Finally, I want to express my deepest gratitude towards my parents who strived hard to educate me. Unfortunately, my father is no more to see this day. I humbly dedicate this piece of work to his loving memory.

J.D. Jadhav

Place : Pune

Date : 28\6\91

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LIST OF PLATES

LIST OF ABBREVIATIONS

c/sec	counts per second
cm/m	centimeter per meter
Cu	Consumptive use
CRI	Crown Root Initiation
ET	Evapotranspiration
gm	grams
IW/CPE	Irrigation water/Cumulative Pan Evaporation
kg	Kilogram
Kc	Crop coefficient
KMPH	Kilometer per hour
mm	millimeter
mb	millibar
MJ/d	Mega joule per day
m/sec	meter per second
PGS	Physiological growth stage
q/ha	quintal per hectare
WUE	Water use efficiency

ABSTRACT

STUDY OF EVAPOTRANSPIRATION OF WHEAT CROP IN VARYING SOIL MOISTURE CONDITIONS

by

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1991

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The present investigation to study the evapotranspiration, water use efficiency, and crop coefficient of wheat crop in varying soil moisture conditions was conducted by laying out a field experiment on the Agronomy Farm at College of Agriculture, Pune-5 during the post-rainy season of 1989-90. The objectives of the investigation were to study the evapotranspiration, water use efficiency at different soil moisture depletion levels, to work out the crop coefficient at different growth stages and to schedule the irrigation of wheat crop for optimum yield. The experiment has seven treatments and was replicated two times.

The irrigation was given to each treatment as per IW/CPE ratio. The soil moisture was taken just before irrigation with the help of neutron probe. The evapotranspiration (ET) was calculated by using soil moisture depletion method. The various biological observations like leaf number, plant height, total dry matter and its components, leaf area and leaf area index were recorded at various physiological growth stages. The potential evapotranspiration (PET) was calculated by using modified Penman method. The vapour pressure deficit (VPD) was calculated by using psychrometric chart. The data required for calculations of

ABSTRACT (Continued)

PET and VPD like maximum and minimum temperature, bright sunshine hours, open pan evaporation, vapour pressure etc. was collected from the Central Agricultural-Meteorological observatory located on the farm of the College of Agriculture, Pune-5. The experimental field was 400 meter away from the observatory. The water use efficiency was calculated by taking the ratio of total dry matter produce to consumptive use. The crop coefficient was calculated at different physiological growth stages by taking the ratio of AET to PET.

Evapotranspiration increased with the increase in number of irrigations as per IW/CPE ratio. Treatment with IW/CPE of 1.0 which was given five irrigations showed the highest evapotranspiration while the treatment with IW/CPE of 0.4 which was given two irrigations showed the lowest evapotranspiration. The other treatments were in between the above two treatments. Growth characters such as plant height, number of tillers, number of functional leaves, leaf area and dry matter were observed to be by and large proportionate with increase in irrigation number. Yield contributing character such as length of earhead, number of spikelets, number of grains, grain weight per earhead and thousand grain weight also increased as the number of irrigations increased.

Treatment with IW/CPE of 0.7 which was given three irrigations, shows the highest water use efficiency. Crop coefficient values are useful in scheduling irrigation to wheat at various growth stages. Increase in evapotranspiration gives more dry matter production and thus yield. In this experiment IW/CPE of 1.0 gave highest potential yield. But the increase in number of irrigations beyond certain limit may not be profitable when the cost of irrigation is taken in to account. In the present study treatment with IW/CPE of 0.7 was found to be the best in respect of water use efficiency.

(185 pages)

1. INTRODUCTION

1 . INTRODUCTION

Wheat is one of the most important food crops of the world and a premier food-grain crop of India. It is said that the story of wheat is the story of cultivation in India. If rice is the staple food of half the world, wheat is the food of the other half of the world. Although wheat is grown under a wide range of climatic conditions, the most extensive production of wheat is in the areas where winters are dry and cool. It has been an anchor sheet of green revolution in India.

Percentage of wheat production to that of total cereal production in the country has increased from 13.7 per cent in 1965 to about 30 per cent at present. The yearwise area and production of wheat in Maharashtra State and India is given in Table 1.

Table 1. Year-wise area and production of wheat in Maharashtra and India

Sr. No.	Year	Maharashtra		India	
		Area x 10^5 ha	Production x 10^5 tonnes	Area x 10^5 ha	Production x 10^5 tonnes
1.	182-83	10.23	8.03	235.67	427.94
2.	1983-84	11.83	11.42	246.72	454.76
3.	1984-85	9.89	8.57	235.65	440.69
4.	1985-86	8.82	6.44	229.97	470.52
5.	1986-87	7.35.	5.36	228.11	455.77

It is obviously clear from the above table that the wheat production in Maharashtra has been decreasing. In wheat production the state ranks much lower, than Punjab, Haryana and Uttar Pradesh. The production in Maharashtra is less due to lack of irrigation. In Maharashtra only 12.7 per cent land is under irrigation as against national average of 23.4 per cent. The ultimate objective of irrigating any crop is to supplement soil moisture for its optimum growth and yield. The quantity of water available for irrigation to a wheat grower may range from very limited to just adequate. Since, farmers grow sugarcane and other cash crops if sufficient water is available, cereal crop such as wheat gets low priority.

The soil moisture is a critical factor in crop growth; hence irrigation is of a paramount importance for increasing wheat yield. It is essential that crop should not suffer moisture stress at any stage of crop growth to achieve the potential yield. Any setback through moisture stress at any growth stage affects the crop growth and in turn crop yield. The reduction in yield is in proportion to the degree and duration of the moisture stress crops suffered. However, crop response does differ in respect of resistance to moisture stress depending upon their anatomical and physiological adaptation. It has been amply proved, however, that the total number of irrigations is not as much important as the timely and adequate irrigation for maximizing wheat yield (Dastane, 1972).

Amongst all the post monsoon (rabi) crops, irrigation scheduling of wheat has received the greatest attention. The major factor to control the plant water status is the resultant rate of transpiration. Hence, to study the evaporative demand of crop, pan evaporation values were used for scheduling irrigation (Sharma et al., 1987). More number of irrigations to some extent increased wheat grain yield. But this increase in grain yield may not be economical if the cost of irrigation is taken into account.

Irrigation being an age old important practice, agronomists in the past studied irrigation problems with the generalized principles of irrigation scheduling, namely, fixed time intervals and thus tried to give general recommendations with less considerations to the soil moisture status, effective rainfall, stage of the crop etc. This traditional approach of irrigation scheduling at fixed intervals was observed to be incapable of further scientific interferences Penman (1948) proved that the consumptive use of water of a crop and rate of evaporation from an open pan are closely related. Hence, irrigation scheduling on the basis of evaporation rates from the open pan evaporimeter provides a scientific basis and is amenable for further inference.

Amongst the several recognized criterion of irrigation scheduling, critical stage approach has been observed to be very useful under definite set of conditions. Evaporative demand of climate is one of the main factors in determining the water requirement of crops. The critical stage approach is suited under the conditions of adequate water supply. When the land is completely covered with vegetation and the crop is in actively growing phase, the water is utilized by the crop mainly due to evaporative demand of the climate. But if the water is not available at this stage, crops experience stress and yield is drastically reduced. Hence, it is necessary that whatever water is available, it must be efficiently and economically used for optimum crop production.

The consumptive use of a crop is the amount of water lost due to evapotranspiration and utilized by the plant for its metabolic activities, which is insignificant (less than 1 per cent of ET). Thus, the term 'CU' is generally taken as equivalent to ET. The factors affecting evapotranspiration are soil factors, such as: soil type, soil texture, soil structure, soil moisture, etc.; crop factors, such as: type of crop, population, density, depth of rooting, leaf area, etc. and meteorological factors such as: net radiation, temperature, humidity, wind, etc.

The estimation of actual evapotranspiration and potential evapotranspiration are made by the methods listed below:

A. Climatological methods:

- i. Thornthwaite method
- ii. Blanney-Criddle method
- iii. Makkink method
- iv. Christiansen method
- v. Penman method

B. Micrometeorological methods:

- i. Mass-transport (Dalton's) method
- ii. Aerodynamic method
- iii. Bowen ratio energy balance method
- iv. Eddy co-relation technique

C. Principle method for direct measurement:

- i. Lysimeter experiments
- ii. Water balance method

Amongst the above, climatological methods are easy and simple. The climatic data, such as air temperature, relative humidity, sunshine hours, open pan evaporation, etc. are available in the meteorological observatory. But the data are relevant to wide region and not specifically for any field conditions. In the direct measurement methods, lysimeter experiment is the best one, but its installation and cost is prohibitive. In water balance studies, soil moisture is measured with the help of gravimetric method, tensiometer, pressure plate technique, electrical resistance, neutron probe, etc. Amongst these the gravimetric method is the most reliable and accurate method of soil moisture measurement. But it requires more time and labour. Therefore, now a days, soil moisture is measured with the help of a neutron moisture meter, which is a fast response technique. It is also simple, less time consuming and needs minimal manual work. The main objectives to review various ways of measuring actual evapotranspiration is for successful applications which are as follows:

1. To determine water balance components of area of catchment;
2. To determine need for irrigation and quantity of water
   i. for planning major projects,
   ii. for design of farm system, and
   iii. for scheduling irrigation of a farm;
3. To validate water balance models, and regional evapotranspiration yield models;
4. To determine water use efficiency and thus in maximizing efficient use of water; and
5. To improve understanding of basic transport phenomenon in the soil-plant-atmosphere continuum.

Crop coefficient refers to the evapotranspiration of a disease free crop grown in large fields under optimum soil water and fertility conditions. Crop coefficient values express full production potential in the given growing environment. The crop coefficient is defined as the ratio between maximum crop evapotranspiration (ET_c) and the reference crop potential evapotranspiration (PET) estimated from the Penman formula. The crop coefficient values are useful in scheduling of irrigation at various growth stages.

Water use efficiency is the ratio of crop yield (Y) to the amount of water depleted by the crop in the process of evapotranspiration (ET).

$$WUE = \frac{Y}{ET}$$

Lemon (1970) suggested actual water use efficiency in modern day agricultural systems. For these calculations, he assumed that 60 per cent of the solar energy is consumed in evapotranspiration. He showed that the best intensive farming results in conversion of one per cent of the solar radiation and produces 0.7 to 1.2 kg of dry matter per tonne of water used. Subsistence farming may produce solar energy fixation of 0.1 to 0.2 per cent and dry matter production less than 0.2 kg per tonne of water consumed. A number of factors are compelling to improve water use efficiency essential in crop production. These factors are:

1. Declining supplies of irrigation water in certain parts of the world;
2. Increasing cost of energy required to deliver irrigation water where it is needed;
3. Growing demand for food, feed and fibre; and
4. Increasing pressure to expand production into more arid environments.

Knowledge of evapotranspiration-yield (ET-Y) relationship is fundamental in evaluating strategies for managing limited water for irrigation. Relationship between evapotranspiration (ET) and grain yield (Y) or dry matter was linear. However, water use efficiency decreased as ET decreased from maximum (Garrity et al., 1982). In the proposed investigation, the relationship between evapotranspiration, grain yield and water use efficiency of wheat crop are to be worked out so that irrigation could be scheduled for optimum yield. The optimum soil moisture for maintaining high production so determined could be estimated which would be helpful in managemental aspects.

With these considerations in view, the field investigation namely, " Study of evapotranspiration of wheat crop in varying soil moisture conditions" was carried out at the Agricultural College Farm, Pune, during 1989-90 with the following objectives:

1. To study evapotranspiration of wheat crop at different soil moisture depletion levels;

2. To study water use efficiency of wheat crop at different soil moisture depletion levels;

3. To work out crop coefficients of wheat crop at different growth stages for Pune; and

4. To decide irrigation scheduling of wheat crop for optimum yield.

2. REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

It is necessary to maintain the soil moisture at optimum level throughout the growth of a crop for maximum growth and yield. In other words, the soil moisture potential should be maintained at higher level, so that the crop need not work against the negative water potential. However, irrigation facilities may not be adequate under all situations to comply with above contention. Even if its economical aspects are neglected various factors such as climate, soil fertility and the available soil moisture affects the crop yield. Availability of moisture at different periods of growth affects the production capacity of the soil and the crop yield. It is, thus, necessary to understand the relationship between water supply and the performance of crop in terms of growth and yield.

Water requirement or consumptive use of water for wheat crop has been studied by several workers from various angles, depending upon the type of situation existing at a given place. The following pages are devoted for outlining the review of literature in respect of the irrigation aspects of wheat crop.

2.1 IRRIGATION REQUIREMENT OF WHEAT CROP:

Water management studies on wheat have gained the paramount importance in India. The winter rains are often inadequate and undependable and thus the supply of moisture to plants do not generally keep pace with the optimum moisture requirements for growth, particularly at the critical periods. The seasonal rainfall, the depth of irrigation water, stored soil moisture, crop situation and atmospheric demand are the main components which determine the water requirements of crop in the field.

Most of the work on water requirement of wheat has been done in Uttar Pradesh, Punjab, Delhi in India which are the principle wheat growing states in the country. On review of the experiments no uniform recommendation pertaining to the number of irrigation to be applied to wheat crop was found. Some research workers advocated one irrigation (Bhattacharya, 1954; Reheja 1961; Pandey and Haque, 1965; Pandey and Mukherji, 1968 and Chauhan et al., 1970) others two irrigations (Bhattacharya, 1954; Raheja, 1961; Pandey and Mukhtar Singh, 1968 and Chauhan et al., 1970). The number of irrigations thus might have been different because of differences in the soil moisture conditions, the soil moisture retensive capacity and also because of seasonal variations of climatic factors such as rainfall, temperature, humidity, evaporation etc.

2.2 WATER REQUIREMENT OF WHEAT CROP:

Singh and Dastane (1970) at New Delhi revealed that the yield of wheat grain increased with wetness of regimes. The yield of the treatment in which six irrigations were applied at 0.25 atm tension was found higher than the treatments in which four and three irrigations were applied at 0.50 and 0.75 atm. tension respectively. The soil moisture was recorded at 22 cm. depth in all the three treatments.

Gowda (1972) obtained the highest grain yield in the treatment in which 360.7 mm water at 50 mm CPE was applied while the lowest yield was obtained in the treatment in which 227.4 mm water at 100 mm CPE was applied.

Prihar et al. (1973) studied schedule of irrigation for wheat. In his study each irrigation of 6 cm, was applied at IW:CPE ratios of 0.5, 0.75 and 1.0 out of which IW:CPE ratio of 1.0 gave maximum grain and straw yield.

Prabhakar et al. (1981) found out that irrigating the crop at 1.05 IW:CPE ratio with 4 and 6 cm depths of water produced higher grain yield compared with other ratios. The water requirement ranged from 267 to 383 mm with 0.60- 1.05 IW:CPE ratios to 413 mm with 20% ASMD regime.

Malavia et al. (1987) reported that scheduling irrigation based on IW:CPE ratio of 1.2 recorded significantly higher values of yield attributes and grain yield of wheat.

English and Nakamura (1989) studied the relationship between wheat yield and irrigation frequency and found that

(i) High frequency irrigation did not increase yield under full irrigation, nor did it mitigate the effects of deficit irrigation. The highest yield was obtained with a relatively long irrigation interval of two weeks.

(ii) Low irrigation frequencies did not further reduce yields under deficit irrigation.

2.3 EVAPOTRANSPIRATION

Prashar and Singh (1963) in their irrigation studies on wheat at New Delhi computed ratios of consumptive use values to evaporation from the U.S. open pan evaporimeter. The values range from 0.52 to 0.56 in 1958-59 and from 0.41 to 0.54 in 1959-60. They observed that the consumptive use increased with the advancement in season from 0.8 to 4 mm per day during heading and grain development stages.

Singh (1968) studied at Udaipur relation of consumptive use of water of wheat with values computed with Blanney and Criddle's formula and the U.S. open pan evaporimeter. He found that the stage of growth did not affect water use by wheat during its active growth period.

Singh and Dastane (1970) correlated water use by wheat with values of evaporation from the U.S open pan evaporimeter for different periods. The total consumptive use of wheat was about 470 mm, the corresponding value of evaporation from the U.S. open pan being 600 mm.

Gupta and Dargan (1970) observed the values of consumptive use of wheat during 1967-68 and 1968-69 ranging between 239.08 to 353.08 and 179.13 to 298.36 mm, respectively. They have also calculated the daily rate of water use of wheat as 4.3 and 3.9 mm during 1967-68 and 1968-69, respectively. The rate of water use by the plant was low in early stages and the peak periods of water use occurred between early to grain development stages.

Patil and Khuspe (1978) reported that the increase in irrigation frequency increased seasonal and daily consumptive use. Seasonal consumptive use varied from 163.7 to 409.4 mm in 1975-1976 and from 179.8 to 516.7 mm in 1976-77. The increase in irrigation frequency, increased the consumptive use, thereby decreased the moisture use efficiency because of less proportionate yield per unit of water consumed by wheat crop in both the seasons.

Rao and Bhardwaj (1982) indicated that computed consumptive water use was very close to the actual evapotranspiration values obtained at adequate irrigation frequency (0.5 atm. tension) in the investigation. The actual consumptive water use under one and two irrigations were far below to that of computed values.

Reddy and Venkatachari (1982) observed the daily rate of water use ranged between 2 to 3 mm per day during first month, 3 to 4 during second month, peak (4.1 mm per day) at about 75 days and decline there after under 40 per cent depletion regime. The seasonal consumptive use of wheat crop in 40 per cent depletion regime varied from 30 to 30.2 cm in experiments conducted from 1969 to 1973, under 80 per cent moisture depletion regime it ranged from 20.96 to 23.14 cm.

Reddy et al. (1985) found that maximum consumptive use of water 383.5 mm was with IW/CPE ratio of 1.05 at 6 m depth of irrigation, while minimum 267.1 mm was with 0.60 ratio at the same depth of irrigation. The increase in consumptive use of water with increase in IW/CPE ratio might be due to frequent wetting of soil surface which might have given maximum opportunity for direct evaporation.

2.4 IRRIGATION APPLIED AT CRITICAL GROWTH STAGES:

Critical stage approach from the irrigation view point for wheat has been the subject of study for several years.

Pandey and Mukherji (1968) noted that the first watering one month after sowing and the second just before flowering were beneficial in augmenting wheat yield.

Singh and Dastane (1970) at New Delhi pointed out that, the yield had increased with wetness of the regimes. They also recommended at least four irrigations for the wheat crop.

Prihar et al. (1974) observed IW/CPE of 0.75 irrespective of growth stage produced as much grain yield as irrigation at five growth stages. But the former, on an average, received 120 mm less irrigation. There was no gain in the yield by combining the IW/CPE with growth stages. These results indicated that irrigating wheat, sown after a pre sowing irrigation, on the basis of IW/CPE, irrespective of growth stage, offers a practical means to economize irrigation water without reduction in yield.

Surajbhan (1977) revealed that first irrigation of 6 cm depth at crown root initiation stage followed by 3 irrigations each of 8 cm depth given after cumulative pan evaporation of 89 mm (IW/CPE ratio of 0.9) resulted in maximum yield as well as profit.

Jana and Sen (1978) studied the effect of irrigation at different growth stages on the growth and yield of dwarf wheat at Nadia (West Bengal). The study revealed that grain and straw yield were affected by the moisture stress at crown root initiation and tillering stages. Three irrigations at crown root initiation, tillering and dough stages with rainfall at flowering stage were sufficient. For two irrigations, the important stages for irrigation are crown-root initiation and tillering and for one irrigation it is the crown root initiation stage.

Singh et al. (1987) found the one irrigation at crown-root-initiation (CRI), two irrigations at CRI and flowering (F), three irrigations at CRI, late jointing (LJ) and milk stages (M) stages, four irrigations at CRI, late tillering (LT) LJ and five irrigations at CRI, LT, LJ, F and M stages were most suitable irrigations schedules. Irrigation at CRI was inevitable for higher yields.

2.5 EFFECTS OF IRRIGATION ON PLANT CHARACTERS:

2.5.1 Plant Height:

Prashar and Singh (1963) conducted an experiment in which they observed that the height of the mother shoot increased significantly with increase in the number of irrigations from one to three.

Shrotriya et al. (1970) conducted an experiment to study the effects of irrigation at critical stages of growth in dwarf wheat. Treatments in this study were six physiological stages of plant growth viz., crown root initiation, late tillering, late jointing, flowering, milk and dough. Plants were subjected to moisture stress by holding with one or two irrigations. Soil moisture stress during early stages of plant growth viz., crown initiation and late tillering gave poor vegetative growth.

Patel et al. (1971) found that plant height was distinctly affected by moisture stress at various stages in both the seasons.

Tomar et al. (1976) studied the effect of intensive V/S extensive irrigation. The results indicated that application of increasing levels of irrigation had significantly affected the plant height.

Jana and Sen (1978) conducted the experiment with 15 treatments comprising irrigation at crown root initiation, tillering, flowering and dough stages. They studied the effect of the stages of irrigation on the growth and yield of dwarf wheat and observed that plant height was significantly influenced by moisture stress at various stages of growth.

Sambasivarao and Tomar (1982) conducted an experiment with four irrigation treatments I_1 - Irrigation at (CRI) crown root initiation;. I_2 - Irrigation at CRI + Flowering and I_4 - Irrigation at CRI + Max. tillering + Flowering. The results indicated that the plant height was significantly higher in I_2 and I_4 than in I_1 and I_3 irrigation levels.

The effects of irrigation on yield contributing characters and yield of wheat is given below.

2.5.2 Tillering:

Number of tiller is an important yield contributing factor in wheat. It has been observed by many research workers that tillering is influenced directly by moisture supply.

As per soil moisture studies on growth of wheat made by Prashar and Singh (1963) number of culms increased with number of irrigations from one to three.

Sekhon et al. (1968) observed that the number of tiller per plant increased with increase in the number of irrigations.

Misra et al. (1969) pointed out that with holding irrigations (in the absence of rains) at the crown root initiation and flowering stages adversely affected tillering and thereby grain yield of dwarf wheat.

Verma et al. (1970) found that the effect of frequencies of irrigations on wheat variety HY-65 at tillering stage indicated more number of healthy tillers which directly reflected upon the yield.

Patel et al. (1971) conducted an experiment on critical stages for irrigation in dwarf variety Kalyan Sona and observed that the moisture stress at crown root initiation and late tillering significantly reduced the tiller number per plant.

Jana and Sen (1978) found the number of effective tiller was significantly influenced by irrigation frequencies. Smaller plants were produced in most of cases where irrigation was withheld in early stages of growth. Number of effective tillers was significantly more with irrigation at crown root initiation or at tillering or at both these stages.

Strak and Longley (1986) observed that tillers developed under optimal soil moisture conditions exhibited uniform appearance patterns and reached maximum population. Soil water deficits decreased the rate of appearance of all main stem tillers and caused appearance to occur over longer intervals. Dry soil conditions also severely reduced development of tiller at the coleoptilar node. When stressed plants were finally irrigated, the appearance rate of affected tillers frequently increased. In some cases, the stimulation of tillering was sufficient to compensate for earlier tiller losses. However, periods of stress extending into the latter part of the vegetative period often reduced maximum tiller population.

2.5.3 Length of Earhead:

Patel et al. (1968) reported that yield attributing characters were adversely affected by moisture stress at any of the stage of crop growth. Moisture stress at crown root initiation and late tillering significantly reduced the length of earhead.

Sekhon et al. (1971) at Hissar observed that earhead length increased with the increase in the number of irrigations from one to three. They further found that with application of one irrigation only there was maximum increase in the earhead length when the water was applied at late tillering stage.

Tomar et al. (1976) indicated that application of increasing level of irrigation had significantly affected earhead length.

Jana and Sen (1978) observed delaying first irrigation beyond flowering stage significantly reduced the ear length.

Pandey et al. (1985) indicated that IW/CPE ratio of 1.0 proved better than 0.6 for significantly influencing length of earhead.

Kattimani et al. (1986) found that optimum irrigation given at critical growth period increases the earhead length and missing the irrigation at any stage reduces the earhead length.

2.5.4 Number of Spikelet Per Earhead:

Shrotriya et al. (1970) at Durgapur revealed that 4 to 6 irrigations applied at different critical stages of crop growth did not significantly affect the number of spikelets per earhead.

Jana and Sen (1978) concluded that irrigation at crown root initiation stage is necessary for synchronous tillering which influence number of ears. Irrigation omitted at further physiological stages reduces the spikelet number per earhead.

Sharma et al. (1981) found the highest number of spikelets under the treatment having 0.50 atm. tension treatment which differed significantly with other treatments.

Ashok Kumar (1986) observed that increasing irrigation increases the spikes per earhead.

2.5.5 Number of Grains Per Earhead:

Singh (1952) stated that lack of moisture at tiller initiation, flowering and grain formation stages affected the number of grains per earhead.

Patel et al. (1971) found in dwarf wheat that the moisture stress at crown root initiation and late tillering significantly reduced the grain number per earhead.

Jana and Sen (1978) stated that highest number of grains per panicle was found with 4 irrigations which was significantly different from one irrigation applied at crown root initiation and tillering stages.

Sharma et al. (1981) recorded the highest number of grains per spike under treatment having 0.50 atm. tension which differed significantly with other treatments.

The lowest number of grains per spike (30.7) were obtained when irrigations was scheduled at 4.00 atm. tension.

Prabhakar et al. (1981) found that when the irrigations were scheduled at frequently intervals (0.60 to 1.05 IW/CPE ratio and irrigation at 20 per cent ASMD) the number of grains per earhead increased.

Ashok Kumar (1986) found that in all six irrigations applied at each physiological stage increased the number of grains per earhead.

2.5.6 Thousand Grain Weight:

Wilson (1969) observed that, stress applied before ear emergence increased 1000 grain weight compared with plants receiving regular irrigation stress after ear emergence decreased 1000 grain weight.

Misra et al. (1969) recorded that withholding irrigations (in absence of rains) at the crown root initiation and flowering stages adversely affected 1000 grain weight in dwarf wheat variety named Herma Rajo.

Patel et al. (1971) concluded that the thousand grain weight was adversely affected by moisture stress at flowering, milk and dough stages.

Patil and Khuspe (1978) concluded that the moisture stress at lower level of irrigation viz. 130 mm CPE (T_1) had adversely and significantly affected thousand grain weight.

Kattimani et al. (1986) concluded that missing irrigation at critical stages adversely affected the 1000 grain weight.

Prasad et al. (1989) found that there was significant difference in 1000 grain weight due to levels of irrigation. Higher frequencies of irrigation scheduled through any of the methods resulted in more test weight compared with lower frequencies, except in 0.5 and 0.7 bars and 50 per cent and 70 per cent available soil moisture. Increase in the test weight under high frequencies of irrigation was owing to adequate water supply, resulting in proper functioning of all bio-chemical processes in the plant system and maintenance of desired water potential in the soil-plant atmospheric system.

2.5.7 Grain Yield:

Research work on irrigation requirement of different crops up to 1945 was based on transpiration ratio approach. Subsequently it was based on "Depth - Interval - Yield" and "Critical Stage" approach. However, as there were many lacunae in these methods "evapotranspiration approach" and "climatological approach" gained support and became the basis for research. The research work thus carried in India and abroad is reviewed briefly in the following paragraphs.

Ekbote and Ingle (1959) reported that the yield of wheat continued to increase up to four irrigations with an intensity of 50, 75 and 100 mm per irrigation.

Jensen and Sletten (1965) observed 20 per cent reduction in the grain yield with 10 per cent reduction in seasonal evapotranspiration in delayed irrigation treatment.

Mukherji and Chatterji (1967) reported that in Uttar Pradesh, the optimum irrigation frequency during the crop growth period varied from one to three in different districts for tall Indian wheat varieties. Low number of irrigation was due to availability of winter rains and contribution from ground water table. The maximum increase in yield of 188 per cent was observed at Etawah with two irrigations.

Verma et al. (1970) at Madhya Pradesh (Powerkheda) found that application of three irrigations to HY 65 at early tillering, flowering and milk stages gave significantly higher yield in their research study conducted in 1960-61. The differences between three and four irrigations were not significant. The highest yield of 18.79 per hectare was recorded with three irrigations.

Patel et al. (1971) recorded that grain yield was adversely affected by moisture stress at any of the stage of crop growth. The maximum grain yield was obtained in treatment with six irrigation given at each of the six physiological stages of growth i.e. crown root initiation, late tillering, late jointing, flowering, milk and dough stage. Yield decreased with decrease in irrigation frequencies from six to four. They also concluded that the crown root initiation and dough stage are the most critical periods for irrigation. Irrigation at late tillering, flowering and milk stage should be given for higher grain yield. While irrigation at late jointing can be skipped off and time can be adjusted with five irrigations.

Patil and Khuspe (1978) concluded that irrigations scheduled at 40 and 70 mm CPE in 1975-76 and at 40 mm CPE in 1976-77 significantly increased the grain yield.

Prihar et al. (1974) showed that the highest yield of 44.55 quintals per hectare was obtained with IW/CPE = 1.0 during the entire growing season.

Rafey et al. (1978) observed that the yield decreased by 9 per cent, 15 per cent, 19 per cent at intervals of irrigation decided on the basis of 0.75 IW/CPE ratio instead of 0.9 IW/CPE ratio at the crown root initiation stage to maximum tillering, maximum tillering to flowering and flowering to maturity.

Agarwal and Yadav (1978) revealed that three and four irrigations gave significantly higher yield as compared to one and two irrigations.

Rao and Bharadwaj (1979) at New Delhi concluded that the effect of irrigation on grain yield was significant during both the years i.e., 1976-77 and 1977-78. A strong correlation was found between the irrigation frequencies and grain yield. The maximum mean grain yield for two seasons was obtained when the crop received irrigations at 0.5 atm. tension at 25 cm soil depth. Appreciable reduction in grain yield was noticed 45 (quintal per hectare) when the irrigations given at crown root initiation and boot stages of crop but this was further reduced to 43 quintals per hectare when the irrigation was restricted to CRI stage alone.

Sharma et al. (1987) indicated that irrigating the wheat crop at 5.0 cm CPE gave best yield amongst 5, 7.5, 10.0, 12.5 and 15.0 cm CPE treatments and was equally effective as irrigating the crop at all physiological stages.

Singh et al. (1987) found that all the irrigation treatments recorded significantly higher grain yield (39.89 quintals per hectare) was obtained with six irrigations applied at crown root initiation (CRI), late tillering (LT), late jointing (LJ), flowering (F), milk (M) and dough (D) stages of crop growth. Moisture stress at CRI, LT, F and D stage caused 25.9, 10.0, 15.4 and 8.3 per cent reduction in grain yield.

Malavia et al. (1987) found that scheduling irrigation based on IW/CPE ratio 1.2 gave significantly higher values of yield attributes and grain yield in wheat.

Tripathi (1989) concluded that one irrigation at crown root initiation stage increased the grain yield (6.40 - 9.60 quintals per hectare) significantly compared with no irrigation. But yield due to single irrigation was lower (5.55 - 10.80 quintals per hectare) than that produced by irrigating the crop at crown root initiation, late tillering, late jointing, flowering and milk stages. Two years average yield in the irrigated treatments in clay-loam soil were on par with each other indicating the irrigation need at crown root initiation stage only for optimum yield.

Thus, it can be concluded that the highest grain yield was obtained with the application of 1 to 4 irrigations. The low number of irrigations were due to availability of rains and contribution from ground water table. Some of the research workers have observed that maximum grain yield of wheat was obtained with 8 to 9 irrigations and even up to 13 irrigations. This is because the soils ranged from light to medium black in texture having higher evaporative demand of the climate. The intensity of irrigation also varied from 2" to 4" (50 to 100 mm) per irrigation.

Higher yields were also obtained at a irrigation frequency varying from 1 to 6 by application of irrigations at different critical stages of the crop growth.

In the experiments where irrigations were scheduled according to the climatological approach 4 to 5 irrigations were necessary for highest grain yield of wheat when there was no rainfall.

2.5.8 Straw Yield:

Modgal et al (1968) pointed out that increased moisture supply within the moisture availability range enhanced the per hectare yield of straw.

Gill et al. (1971) reported that the straw yield was more in the plots receiving 8-9 irrigations.

Patel et al. (1971) concluded that straw yield was affected by moisture stress at crown root initiation and late tillering stages in dwarf wheat varieties.

Patil and Khuspe (1978) indicated that in 40 and 70 mm CPE treatment significantly increased the straw yield.

Mehta et al. (1982) found that average effect of irrigation on straw yield of wheat almost followed the trend of grain yield and the total straw yield increased with increase in number of irrigations.

Shaktawat (1980) observed the highest straw yield with 7 irrigations in both seasons of year 1970-71 and 1971-72.

Malvia et al. (1987) in Gujrat conducted experiment on medium clay soil and concluded that straw yield is higher (37.5 Quintals per hectare) with 1.2 IW/CPE ratio in comparison to 1.0 and 0.8 IW/CPE ratio.

2.5.9 Dry Matter Yield:

Gautam (1961) in Uttar Pradesh observed a 10 per cent decrease in the yield of dry matter of wheat when water per irrigation was decreased from 90,000 gallons to 60,000 gallons in canal areas of Agra region of Uttar Pradesh.

Prashar and Mukhtar Singh (1963) from their intensive soil moisture studies on wheat stated that increase in number of irrigations gave higher dry weight. It also increased the evapotranspiration values from 376 to 503 in 1958-59 and 556 to 607 in 1959-60.

Pandey et al. (1986) found that the total dry matter yield of IW/CPE ratio 1.0 was significantly higher than other ratios except in 1979-80 when differences were significant only between 0.6 and 1.0 IW/CPE.

2.6 WATER USE EFFICIENCY OF WHEAT CROP:

Patil and Khuspe (1978) recorded the maximum water use efficiency of 15.87 and 13.87 kg/ha/mm with 70 mm CPE in 1975-76 and with 130 mm CPE in 1976-77, respectively.

Singh et al. (1979) conducted experiment in 1976-77 and 1978-79 and indicated that water use efficiency decreased from low IW/CPE ratio (126.3 to 142.8 kg/ha/cm at 0.60) to high IW/CPE ratio (82.8 to 98.5 kg/ha/cm at 1.05). Depth of irrigation did not bring about any marked variation in water use efficiency.

Mallick et al. (1981) conducted a field experiment in alluvial sandy loam soil during a wet year (1978-79) and a drought year (1979-80) on wheat to estimate its water use efficiency under different irrigation treatments. The water use efficiency values calculated by taking both water depletion and capillary contribution of different irrigation treatment revealed that no irrigation treatment (control) was least efficient in a dry year and increasing the number of irrigation enhanced the water use efficiency. The low water use efficiency under no irrigation treatment during dry year was mainly due to low yields. But in wet year, the water use efficiency values were higher with lesser number of irrigations. Increasing the frequency of irrigation in the wet year resulted in lower water use efficiency probably due to under estimation of the calculated deep drainage.

Prabhakar et al. (1981) obtained maximum water use efficiency with 20 per cent ASMD regime followed by IW/CPE ratio of 1.05.

Reddy et al. (1982) conducted a field experiment under limited and adequate irrigation. They reported that as the irrigation frequency increased from one to adequate, water use efficiency decreased progressively. On an average, the water use efficiency under one irrigation was 11.60 kg/ha-mm while under adequate irrigation it was 10.35 kg/ha-mm. The higher consumptive use resulted in lower water use efficiency under adequate irrigation whereas the reverse was true with limited irrigation (one or two) in which case lesser amount of available soil moisture was more efficiently utilized.

Mujumdar and Mandal (1984) reported that maximum water use efficiency was achieved, when irrigations were applied at an IW:CPE ratio of 0.8 and it was lowest with the IW:CPE ratio of 0.6

Malavia (1985) reported that the WUE on the contrary was higher at 0.8 IW/CPE indicating the efficient water use at lower frequencies of watering.

Ashok Kumar et al. (1986) found that water use efficiency (WUE) decreased with increase in soil water supply. The lower WUE associated with higher soil moisture status was due to proportionately more increase in ET than increase in the grain yield.

Sinha et al. (1986) found that the water use efficiency (WUE) was as high as 139 kg/ha-cm at 0.60 and 97 kg/ha-cm at 1.05 IW/CPE.

2.7 CROP COEFFICIENT:

For higher yields water requirement depends on climate and length of growing period. For irrigation scheduling and hydrological studies, it is often necessary to estimate reference evapotranspiration at points located some distance away from the weather station. Crop coefficient have been used to estimate actual evapotranspiration (ET) of a crop from measurements of potential or reference evapotranspiration (PE). Crop coefficients are the empirical ratio of AE to PE and are derived from experimental data. Coefficients of a crop vary with growth stages and constitute a crop curve. They are used in computerized irrigation scheduling programs. Crop coefficient are normally derived under conditions where growth is not limited by moisture or any other climatological or physiological factors. When moisture stress becomes limiting, the ratio of AE to PE decreases along with yield. Crop curves can be expressed as a ratio of AE/PE verses time (FAO 73). The crop stages are divided into the initial stage, development stage, mid season stage, and late stage. The number of days at each stage is then specified (Doorenbos and Kassam, 1979; Doorenbos and Pruitt, 1977).

Investigations were carried out on wheat to find out crop coefficient values for various stages using consumptive use of water by wheat and PE computed by modified penman equation. The crop stages are crown root initiation, tillering, jointing, flowering, milk and physiological maturity. The crop coefficient values are useful in scheduling irrigation to wheat at various growth stages.

3. MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation to study the evapotranspiration, crop coefficient, water use efficiency and irrigation scheduling of wheat was carried out by laying out a field experiment. The details of the materials used and methods employed during the present investigation are given in this chapter under the following heads.

3.1 DETAILS OF EXPERIMENTAL MATERIALS:

3.1.1 Experimental Site:

The experiment was laid out on the survey No. 53 A of the plot No. 637-639 of E Division of Agronomy Farm at the college of Agriculture, Pune-5 during the post monsoon season of 1989-90. Geographically it is situated at 18° 32' N latitude and 73° 51' E longitude. The height is 559 m above M.S.L. and atmospheric pressure ranges between 930 to 960 mb.

3.1.2 Soil:

Topography of the experimental field was uniform and levelled. The plot has deep black soil with the depth of more than 100 cm. It was a well drained plot. Bulk density of the soil was determined by core-sampler method. Field capacity of soil was determined by the field method. permanent wilting point was determined by using sunflower technique. Mechanical analysis of soil was done by using the International Pipette method (Black, 1965). The textural class of the soil was decided by using the Textural triangle method.

The physical properties of the experimental soil are elaborated in Table 2.

Table 2. **Physical properties of the experimental soil**

Sr. No.	Soil property	Observation
A.	**Physical properties**	
1.	Coarse sand	6.93 per cent
2.	Fine sand	19.10 per cent
3.	Silt	24.72 per cent
4.	Clay	45.65 per cent
5.	Textural class	clay
B.	**Single value physical constants**	
1.	Field capacity	39.51 per cent
2.	Permanent wilting point	23.21 per cent
3.	Bulk density	1.10 g/c.c.

The data regarding the composition and properties of the soil revealed that the soil was deep black having textural class "Clay".

3.2 CLIMATIC CONDITIONS:

The climatic conditions of the location are described under the following heads;

3.2.1 General Climate:

Pune comes under the plain zone (transitional belt) of Maharashtra State. The average annual rainfall of the place is 641.1 mm. Out of the total rainfall about 75 per cent of the precipitation is received through south-east monsoon during June to september, while about 25 per cent is received during the remaining months. From December to May, there is practically a dry spell with abundant sunshine and clear sky. The value of maximum temperature is the highest ranging from 34° to 40°C in the months of April and May, while it is the lowest, ranging from 6.0° to 10°C in the months of December and January.

3.2.2 Climatic Conditions of the Year 1989-1990:

Weekly data pertaining to the various meteorological parameters for the period from April 1989 to March 1990 for Pune are presented in Table 3 and are graphically shown in Fig. 1

Table 3. Weekly average weather data of the period from April 1989 to March 1990

Week No.	Temperature max.	Temperature min.	Sol. Rad.	B.S. Hrs.	R.H. I	R.H. II	Rainfall (mm)	Evaporation	Wind velocity (Kmph)
1	2	3	4	5	6	7	8	9	10
14	37.50	15.20	23.88	10.80	53.50	11.70	7.50	9.50	5.30
15	38.50	18.20	19.77	11.20	54.70	12.40	0.00	10.50	5.40
16	39.20	20.20	20.67	10.20	58.79	18.79	24.70	9.20	6.60
17	37.50	20.00	20.62	10.50	52.70	21.50	0.00	9.90	5.90
18	37.20	21.40	23.19	10.50	63.70	26.70	0.20	9.90	7.50
19	39.50	20.20	27.04	10.50	53.00	17.00	0.00	10.00	8.00
20	37.20	23.60	26.38	10.50	59.00	32.00	0.00	10.70	5.90
21	35.70	22.70	27.34	11.80	68.00	37.00	0.00	10.30	11.80
22	34.90	21.90	21.46	7.00	80.00	47.00	72.50	8.70	14.10

Table 3 (Continued ...)

(Continued ...)

Week No.	Temperature max.	Temperature min.	Sol. Rad.	B.S. Hrs.	R.H. I	R.H. II	Rainfall (mm)	Evaporation	Wind velocity (Kmph)
1	2	3	4	5	6	7	8	9	10
23	32.20	21.90	19.81	6.20	86.00	65.00	46.50	6.70	8.90
24	29.40	22.20	16.90	3.30	86.00	72.00	41.30	5.60	6.80
25	29.90	21.70	21.17	5.80	83.00	65.00	6.20	5.50	8.60
26	29.20	22.10	15.57	3.50	87.00	79.00	20.30	4.50	9.90
27	29.70	22.00	20.38	5.60	86.00	66.00	1.60	4.30	10.60
28	31.10	22.10	20.03	6.20	85.00	67.00	0.10	5.00	10.30
29	29.60	22.10	17.97	3.80	89.00	76.00	25.60	3.50	9.90
30	27.90	21.40	13.15	1.90	90.00	81.00	158.30	2.90	9.20
31	28.50	21.40	17.99	4.40	84.00	77.00	5.50	4.10	12.40
32	28.20	21.40	20.41	4.80	86.00	79.00	8.40	3.30	12.70
33	27.10	20.70	14.23	2.50	90.00	81.00	16.10	2.60	12.10
34	26.90	21.00	13.04	1.30	93.00	88.00	41.10	4.10	9.10
35	27.90	19.90	18.12	3.70	88.19	71.00	4.70	4.10	9.70
36	29.00	19.20	17.41	6.30	90.09	64.00	12.40	4.50	8.60
37	29.60	20.60	21.21	7.20	83.09	59.00	1.00	4.50	7.00
38	31.10	21.10	16.31	4.30	91.80	73.00	36.40	3.00	8.50
39	30.50	20.30	15.51	3.70	95.00	85.00	105.0	3.30	4.40
40	30.90	19.80	19.12	5.40	93.40	56.70	21.50	4.70	3.20
41	34.00	18.30	21.93	9.20	91.19	30.20	0.00	4.20	2.40
42	33.80	15.30	22.20	10.10	88.19	31.50	0.00	4.80	2.40

Table 3 (Continued ...)

(Continued ...)

Week No. 1	Temperature max. 2	Temperature min. 3	Sol. Rad. 4	B.S. Hrs. 5	R.H. I 6	R.H. II 7	Rainfall (mm) 8	Evaporation 9	Wind velocity (Kmph) 10
43	33.10	15.80	21.28	10.20	86.80	29.20	0.00	4.6	2.90
44	32.80	14.40	20.74	10.10	84.69	31.50	0.00	4.50	2.90
45	31.60	14.10	18.23	8.80	75.00	34.09	0.00	4.30	4.10
46	31.60	17.20	19.07	9.70	83.80	43.00	0.00	3.70	5.00
47	31.50	13.00	19.13	10.00	88.09	33.09	0.00	3.90	4.70
48	30.80	11.90	18.33	9.80	88.19	38.40	0.00	4.20	3.10
49	29.40	10.30	18.20	9.60	88.19	34.50	0.00	4.50	4.00
50	28.20	9.60	18.18	9.60	90.50	38.79	0.00	4.20	4.40
51	28.20	10.30	17.49	9.40	87.40	37.50	0.00	3.90	4.50
52	28.40	14.00	15.49	6.10	86.09	42.79	0.00	3.20	4.10
1	30.80	13.50	17.06	9.20	88.80	38.79	0.00	3.40	4.10
2	30.10	10.10	18.55	9.80	87.00	26.79	0.00	4.40	3.40
3	31.90	8.30	19.81	10.00	85.80	21.70	0.00	4.10	3.60
4	31.70	9.10	19.90	10.00	84.00	23.70	0.00	4.70	2.50
5	33.70	10.10	19.05	9.80	83.00	21.00	0.00	4.70	2.90
6	33.10	12.10	19.51	9.80	78.00	29.00	0.00	4.90	2.60
7	32.60	12.90	19.77	9.90	85.00	27.00	0.00	5.30	3.20
8	30.10	8.50	20.28	10.40	85.00	19.00	0.00	6.00	4.90
9	31.90	12.10	22.22	10.10	79.00	29.00	0.00	6.80	4.70
10	31.70	13.10	23.18	10.10	74.00	27.00	0.00	7.80	6.40
11	35.40	15.70	23.50	10.20	81.00	27.00	0.00	7.70	6.70
12	35.60	16.40	22.47	9.60	67.00	23.00	0.00	9.60	5.00
13	34.80	15.60	25.16	10.30	69.00	20.00	0.00	8.50	6.30

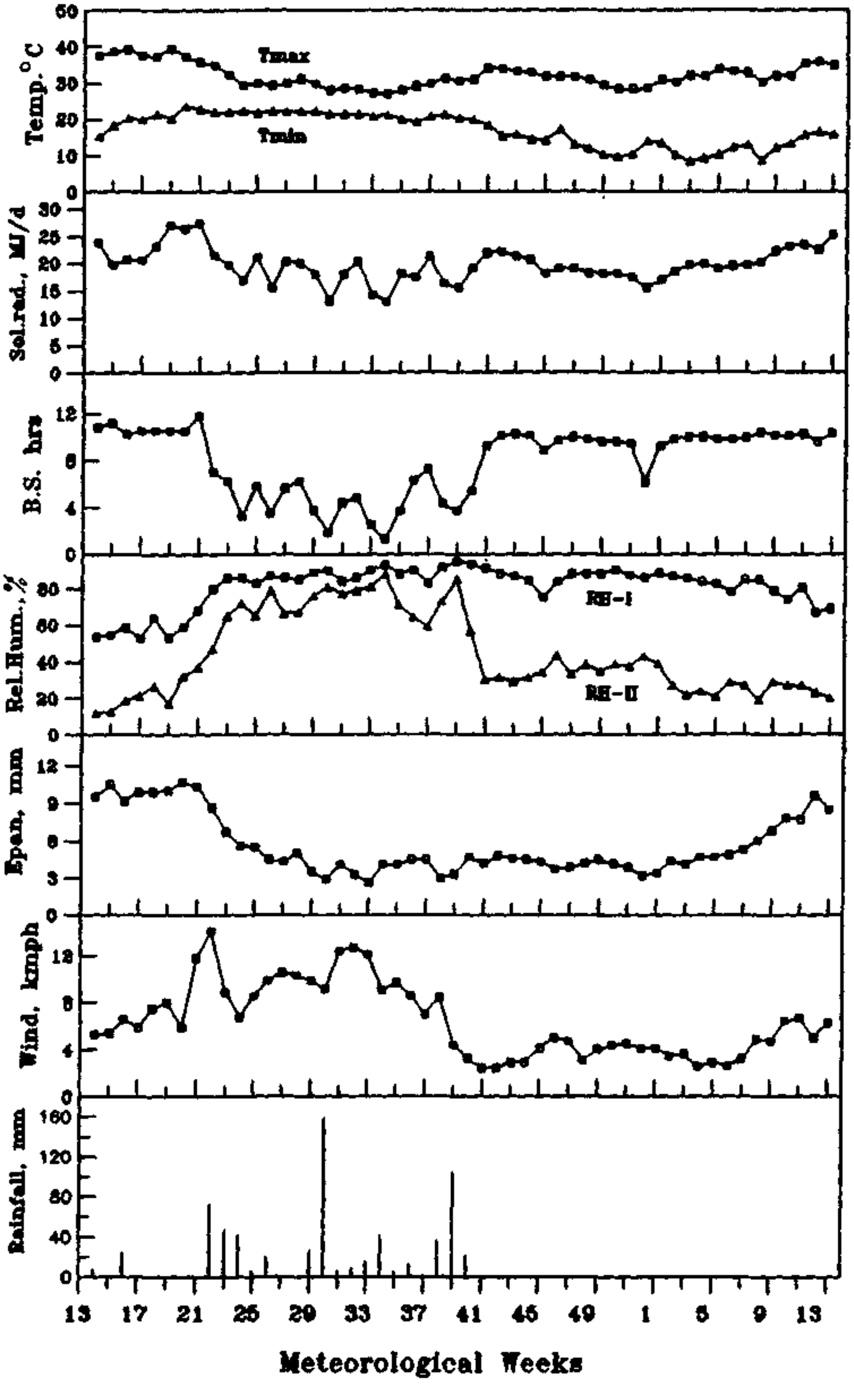

Fig. 1 Weekly average weather data of the period from April 1989 to March 1990

The data reveal that average maximum temperature for the year was 32.64°c. The highest temperature of 39.60°c was observed in the month of May (i.e. 19th meteorological week of 1989), while the lowest temperature of 26.9°c was observed in the month of September (i.e. 4th meteorological week of 1990). The average minimum temperature for the year was 16.67°c. The highest minimum temperature of 23.6°c was observed in the month of May (i.e. 20th meteorological week of 1989), while the lowest minimum temperature of 8.3°c was observed in the month of January (i.e. 3rd meteorological week of 1990).

Total annual precipitation was 657.2 mm. A major part of the rainfall was received in three spells viz. first fortnight of June (160.3 mm), the last week of July (15.4 mm) and the last week of September (105 mm).

The average humidity of the year measured at 7.30 hrs. (Humidity-I) was 81.02 per cent and that measured at 14.30 hrs. (Humidity-II) was 43.43 per cent. Humid conditions existed from June to September with average Humidity-I of 87.4 per cent and average Humidity-II of 71.94 per cent. Dry conditions existed in the month of April with average Humidity-I of 54.93 per cent and average Humidity-II of 16.1 per cent.

The average wind speed of the year was 6.41 KMPH. The maximum wind speed of 14.1 KMPH was measured in the month of June, while the minimum wind speed of 2.4 KMPH was measured in the month of October.

The average daily pan evaporation of the year was 5.72 mm. The maximum pan evaporation of 10.7 mm was recorded in the month of May, while the minimum pan evaporation of 2.6 mm was recorded in the month of August.

3.2.3 Climatic Conditions during the Experimental period:

The daily weather data of the various meteorological parameters observed during the experimental period i.e., from the month of October 1989 to the month of March 1990 are given in Table 4 and graphically shown in Fig. 2

Table 4. Daily weather data during the experimental period from October 1989 to March 1990

Week No.	Date	Temperature Max.	Temperature Min.	Temperature Mean	R.H per cent I	R.H per cent II	Wind Velocity KMPH	B.S. (hrs.)	Pan-evaporation
44	29-10-89	33.80	16.30	25.10	89.00	33.00	2.70	9.90	4.20
	30-10-89	34.10	16.40	25.30	82.00	37.00	3.50	10.10	4.70
	31-10-89	32.50	15.60	24.10	85.00	37.00	6.10	10.20	4.10
	1-11-89	32.80	14.50	23.70	83.00	33.00	5.40	10.50	5.10
	2-11-89	32.10	12.90	22.50	83.00	26.00	4.00	9.60	4.10
	3-11-89	31.80	12.80	22.30	89.00	27.00	3.70	10.50	4.70
	4-11-89	32.50	12.60	22.60	82.00	28.00	3.60	10.40	4.80
45	5-11-89	32.10	12.70	22.40	72.00	29.00	3.30	10.20	3.90
	6-11-89	31.70	13.20	22.50	90.00	27.00	3.30	8.40	4.10
	7-11-89	31.50	12.50	22.00	80.00	25.00	3.20	9.70	3.90
	8-11-89	31.70	12.30	22.00	57.00	23.00	6.40	10.50	4.90
	9-11-89	31.50	12.40	22.00	78.00	38.00	7.10	8.60	5.20
	10-11-89	30.70	17.90	24.30	67.00	49.00	6.00	9.30	5.00
	11-11-89	31.80	17.90	24.90	81.00	48.00	5.50	5.00	3.7

Table 4 (Continued ....)

(Continued ....)

Week No.	Date	Temperature Max.	Min.	Mean	R.H per cent I	II	Wind Velocity	B.S. (hrs.)	Pan-evaporation
46	12-11-89	31.70	17.90	24.80	90.00	40.00	4.90	7.80	3.20
	13-11-89	31.30	16.30	23.80	80.00	50.00	5.20	9.80	4.10
	14-11-89	30.80	17.80	24.30	80.00	53.00	6.30	10.40	4.40
	15-11-89	31.10	17.70	24.40	80.00	52.00	4.80	10.40	3.90
	16-11-89	31.80	18.60	25.20	88.00	44.00	3.50	10.10	4.10
	17-11-89	32.50	17.60	25.10	79.00	33.00	3.60	9.40	4.30
	18-11-89	32.10	14.60	23.40	90.00	29.00	4.30	10.30	4.00
47	19-11-89	32.10	14.80	23.50	92.00	33.00	3.50	9.90	2.80
	20-11-89	30.60	14.70	22.70	93.00	36.00	3.30	10.00	3.60
	21-11-89	32.20	14.00	23.10	94.00	39.00	2.50	9.90	3.80
	22-11-89	32.10	12.00	22.10	80.00	39.00	3.30	10.00	4.40
	23-11-89	31.00	11.30	21.20	87.00	22.00	3.60	10.00	4.40
	24-11-89	31.00	11.20	21.10	83.00	24.00	2.70	10.00	3.70
	25-11-89	31.50	12.90	22.20	88.00	39.00	3.00	10.10	4.00
48	26-11-89	31.50	12.80	22.20	78.00	37.00	3.20	9.90	3.90
	27-11-89	31.00	11.50	21.30	77.00	44.00	3.80	10.00	3.90
	28-11-89	30.70	11.70	21.20	87.00	37.00	2.90	9.90	3.80
	29-11-89	31.70	12.20	22.00	87.00	39.00	2.50	9.50	3.40
	30-11-89	31.50	11.80	21.70	81.00	35.00	3.70	9.60	4.40
	1-12-89	29.70	11.40	20.60	78.00	37.00	5.90	10.10	4.30
	2-12-89	29.50	12.40	21.00	74.00	40.00	6.20	9.70	5.30

Table 4 (Continued ...)

(Continued .....)

Week No.	Date	Temperature Max.	Min.	Mean	R.H per cent I	II	Wind Velocity	B.S. (hrs.)	Pan-evaporation
49	3-12-89	29.60	11.80	20.70	92.00	40.00	6.10	9.80	4.60
	4-12-89	29.80	11.60	20.70	89.00	36.00	4.50	9.60	5.40
	5-12-89	30.00	11.10	20.60	91.00	35.00	3.60	9.80	4.10
	6-12-89	29.60	11.00	20.30	93.00	33.00	3.70	9.60	3.90
	7-12-89	30.10	10.80	20.50	68.00	32.00	4.50	9.20	3.80
	8-12-89	28.70	8.00	18.40	95.00	32.00	3.70	9.80	3.50
	9-12-89	28.50	8.00	18.30	90.00	34.00	4.70	9.90	4.50
50	10-12-89	28.10	8.40	18.30	93.00	38.00	3.50	9.90	4.30
	11-12-89	27.70	9.50	18.60	90.00	38.00	4.90	9.70	3.60
	12-12-89	29.90	10.70	20.30	91.00	41.00	2.10	8.30	3.60
	13-12-89	29.30	10.20	19.80	95.00	42.00	4.00	9.90	3.60
	14-12-89	28.50	10.40	19.50	91.00	40.00	5.30	9.80	4.10
	15-12-89	27.20	10.00	18.60	93.00	41.00	6.40	9.90	4.20
	16-12-89	26.80	8.30	17.60	81.00	32.00	5.70	9.90	4.40
51	17-12-89	26.90	7.60	17.30	88.00	33.00	5.70	9.70	4.50
	18-12-89	26.50	6.90	16.70	84.00	43.00	5.70	9.90	4.60
	19-12-89	26.80	8.70	17.80	79.00	40.00	4.50	9.90	3.70
	20-12-89	28.10	9.70	18.90	95.00	40.00	3.20	9.60	2.70
	21-12-89	29.30	11.80	20.60	93.00	39.00	2.60	9.90	3.20
	22-12-89	30.10	13.60	21.90	87.00	36.00	3.40	7.70	3.70
	23-12-89	30.30	13.90	22.10	86.00	32.00	3.90	9.40	3.40

Table 4 (Continued ....)

(Continued ...)

Week No.	Date	Temperature Max.	Min.	Mean	R.H per cent I	II	Wind Velocity	B.S. (hrs.)	Pan-evaporation
52	24-12-89	30.20	12.00	21.10	93.00	42.00	3.90	9.40	4.70
	25-12-89	28.90	11.50	20.20	95.00	29.00	3.10	8.10	3.40
	26-12-89	28.00	15.40	21.70	78.00	40.00	4.50	4.50	2.70
	27-12-89	26.70	12.30	19.50	72.00	45.00	3.90	5.40	4.30
	28-12-89	26.20	15.80	21.00	70.00	48.00	4.00	6.70	3.70
	29-12-89	27.70	11.60	19.70	91.00	42.00	2.80	4.40	2.60
	30-12-89	30.10	18.20	24.20	92.00	52.00	4.30	6.80	3.20
	31-12-89	29.40	15.20	22.30	98.00	45.00	2.90	3.70	1.60
1	1-01-90	30.80	14.00	22.40	96.00	43.00	3.20	9.40	3.40
	2-01-90	31.60	12.40	22.00	83.00	46.00	3.40	9.40	3.10
	3-01-90	29.80	13.00	21.40	81.00	36.00	3.10	9.10	2.90
	4-01-90	32.50	15.40	24.00	87.00	41.00	3.60	9.40	3.40
	5-01-90	31.10	14.40	22.80	89.00	41.00	3.30	8.00	3.50
	6-01-90	30.10	13.70	21.90	91.00	34.00	3.80	9.70	3.90
	7-01-90	29.70	12.20	21.00	95.00	31.00	3.70	9.90	4.00
2	8-01-90	29.50	9.60	19.60	88.00	28.00	4.80	9.90	4.50
	9-01-90	29.30	11.30	20.30	91.00	33.00	5.40	10.00	4.60
	10-01-90	29.30	12.80	21.10	89.00	32.00	4.30	8.90	4.60
	11-01-90	30.40	11.70	21.10	84.00	27.00	2.80	9.90	3.80
	12-01-90	30.00	8.50	19.30	83.00	28.00	3.10	9.90	4.10
	13-01-90	30.40	8.40	19.40	87.00	23.00	3.40	10.00	5.00
	14-01-90	32.00	8.60	20.30	87.00	17.00	1.70	10.00	4.80

Table 4 (Continued ...)

(Continued ...)

Week No.	Date	Temperature Max.	Min.	Mean	R.H per cent I	II	Wind Velocity	B.S. (hrs.)	Pan-evaporation
3	15-01-90	33.00	8.90	21.00	90.00	21.00	2.00	9.90	4.20
	16-01-90	32.50	7.80	20.20	82.00	26.00	2.40	10.10	5.30
	17-01-90	31.50	8.30	19.90	85.00	26.00	2.10	10.00	2.40
	18-01-90	32.10	8.90	20.50	84.00	23.00	2.60	10.00	3.30
	19-01-90	30.40	9.20	19.80	88.00	20.00	2.60	10.00	4.20
	20-01-90	31.00	7.90	19.50	87.00	17.00	3.30	10.10	4.30
	21-01-90	32.80	7.60	20.20	85.00	19.00	2.70	10.10	4.70
4	22-01-90	32.20	8.60	20.40	85.00	32.00	2.30	10.20	4.40
	23-01-90	30.50	9.00	19.80	81.00	26.00	3.50	10.20	5.90
	24-01-90	31.10	9.30	20.20	88.00	27.00	3.70	10.10	4.50
	25-01-90	31.50	9.20	20.40	90.00	19.00	3.00	10.10	4.50
	26-01-90	31.90	8.50	20.20	81.00	20.00	3.30	10.30	4.80
	27-01-90	32.70	9.40	21.40	78.00	19.00	2.50	10.30	4.70
	28-01-90	32.20	9.80	21.00	86.00	16.00	2.10	10.40	4.70
5	29-01-90	32.20	9.40	20.80	85.00	20.00	2.70	10.40	4.80
	30-01-90	33.50	9.20	21.40	83.00	18.00	2.60	10.40	6.40
	31-01-90	33.80	10.90	22.40	82.00	21.00	2.00	10.20	3.70
	1-02-90	34.70	11.20	23.00	34.00	20.00	2.50	9.80	4.70
	2-02-90	33.90	10.30	22.10	88.00	27.00	3.10	8.90	4.50
	3-02-90	33.60	9.50	21.60	81.00	22.00	2.80	9.20	4.60
	4-02-90	34.10	9.90	22.00	81.00	17.00	2.60	10.00	4.20

Table (Continued ...)

(Continued ...)

Week No.	Date	Temperature Max.	Min.	Mean	R.H per cent I	II	Wind Velo-city	B.S. (hrs.)	Pan-eva-pora-tion
6	5-02-90	34.70	9.80	22.30	88.00	16.00	3.00	10.30	4.20
	6-02-90	33.50	9.90	21.70	81.00	24.00	2.40	10.20	5.00
	7-02-90	33.50	11.80	22.70	67.00	30.00	3.50	10.30	4.90
	8-02-90	32.50	13.40	23.00	70.00	36.00	4.00	10.30	5.50
	9-02-90	31.80	12.40	22.10	81.00	31.00	3.70	9.10	5.40
	10-02-90	31.80	13.20	22.50	81.00	36.00	3.20	7.90	5.10
	11-02-90	33.60	15.00	24.30	80.00	33.00	2.60	10.20	5.00
7	12-02-90	32.80	14.50	23.70	76.00	31.00	4.90	9.60	5.10
	13-02-90	34.40	15.10	24.80	82.00	31.00	2.10	9.60	4.40
	14-02-90	33.00	13.40	23.20	88.00	31.00	4.80	9.60	4.60
	15-02-90	32.60	12.80	22.70	77.00	23.00	5.50	9.40	5.20
	16-02-90	32.60	10.00	21.30	98.00	16.00	5.60	10.30	5.90
	17-02-90	30.80	9.40	20.10	90.00	22.00	4.10	10.00	5.90
	18-02-90	31.60	15.40	23.50	85.00	36.00	7.60	10.50	5.90
8	19-02-90	28.70	6.20	17.50	94.00	20.00	7.00	10.10	7.20
	20-02-90	29.70	6.40	18.10	84.00	14.00	4.80	10.40	6.90
	21-02-90	29.70	7.50	18.60	78.00	26.00	5.40	10.50	5.90
	22-02-90	29.30	9.50	19.40	78.00	17.00	4.30	10.50	5.60
	23-02-90	30.80	9.90	20.40	85.00	19.00	3.90	10.40	5.30
	24-02-90	31.10	9.30	20.20	91.00	14.00	3.40	10.40	5.50
	25-02-90	31.40	10.60	21.00	84.00	21.00	4.20	10.60	5.80

Table (Continued ...)

(Continued ...)

Week No.	Date	Temperature Max.	Temperature Min.	Temperature Mean	R.H per cent I	R.H per cent II	Wind Velocity	B.S. (hrs.)	Pan-evaporation
9	26-02-90	31.60	11.50	21.60	75.00	34.00	3.10	10.60	6.80
	27-02-90	32.70	11.50	22.10	89.00	7.00	4.20	10.50	7.00
	28-02-90	34.10	17.30	25.70	74.00	43.00	7.50	9.00	5.80
	01-03-90	31.60	16.80	24.20	72.00	34.00	10.70	10.60	7.10
	02-03-90	30.30	11.30	20.80	83.00	25.00	7.10	9.80	6.40
	03-03-90	31.70	7.90	19.80	78.00	19.00	5.60	9.90	7.30
	04-03-90	31.60	8.60	20.10	81.00	39.00	6.30	10.00	7.30
10	05-03-90	28.80	12.10	20.50	87.00	32.00	7.60	10.00	8.40
	06-03-90	29.70	14.80	22.30	66.00	33.00	9.80	10.20	7.60
	07-03-90	31.10	12.70	21.90	59.00	29.00	5.70	8.30	5.80
	08-03-90	31.80	10.30	21.10	75.00	26.00	6.90	10.80	8.90
	09-03-90	31.50	13.40	22.50	77.00	17.00	6.10	10.60	7.70
	10-03-90	33.50	12.20	22.90	70.00	19.00	3.70	10.40	7.50
	11-03-90	35.30	16.50	25.90	82.00	29.00	7.00	10.50	8.70
11	12-03-90	32.90	13.40	23.20	88.00	26.00	6.20	10.50	8.80
	13-03-90	34.40	14.30	24.40	90.00	23.00	5.30	10.30	7.20
	14-03-90	35.70	17.10	26.40	84.00	22.00	5.70	10.70	7.20
	15-03-90	35.80	16.60	26.20	90.00	23.00	4.90	9.60	6.90
	16-03-90	36.10	15.50	25.80	73.00	39.00	4.00	10.30	7.40
	17-03-90	36.50	15.50	26.00	73.00	35.00	4.10	10.50	7.50
	18-03-90	36.10	17.20	26.70	68.00	18.00	5.10	9.80	8.80

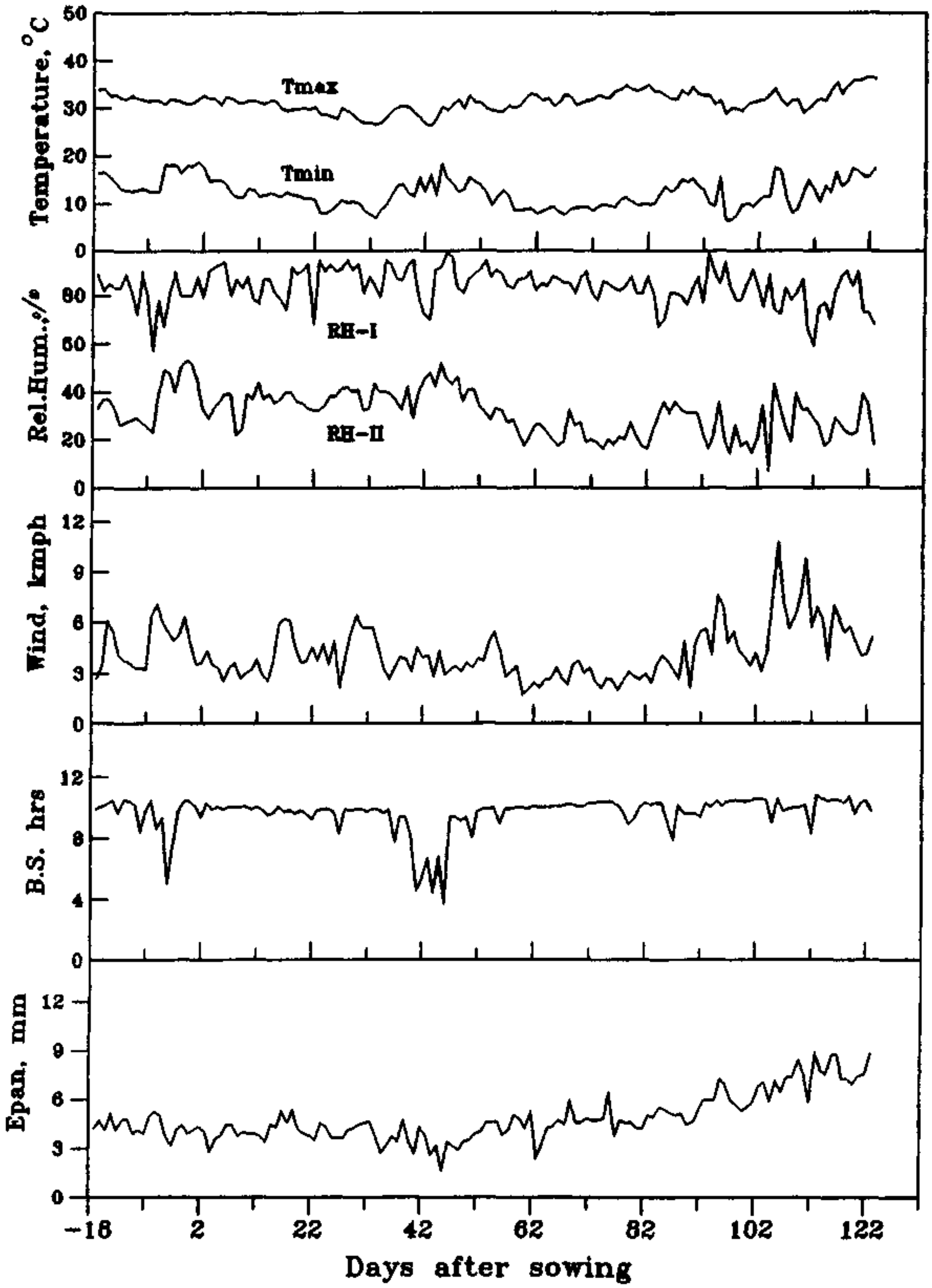

Fig. 2 Daily weather data during the experimental period from October 1989 to March 1990

The data would reveal that the average maximum temperature during the crop growth period was 31.68°c with the range of 28.2° to 35.6°c. Average minimum temperature was 12.38°c in the range of 8.3°c to 17.2°c.

Average relative Humidity-I and Humiditiy-II was 82.29 per cent and 30.27 per cent, respectively. The maximum value of Humidity-I was recorded in the month of December while that of Humidity-II was recorded in the month of November.

The average duration of daily bright sunshine hours was 9.65 hr. during the crop growth period. Maximum weekly average of bright sunshine hours i.e. 10.4 hr. was observed in the 8th meteorological week of 1990, while the lowest weekly average of bright sunshine hours i.e. 6.1 hr. occurred in the 52nd week of 1989.

Average daily wind speed was 4.39 KMPH. The average pan evaporation was 5.33 mm within the range of 3.2 to 9.6 mm. There was no occurrence of rainfall during the crop growth period.

3.3 CROPPING HISTORY OF THE EXPERIMENTAL PLOT:

Details of the cropping history of the experimental plot for the previous three years are given below:

Year	Crops grown		
	Kharif	Rabi	Summer
1986 - 1987	Sunflower	Wheat	Fallow
1987 - 1988	Maize	Wheat	Fallow
1988 - 1989	Sunflower	Wheat	Fallow
1989 - 1990	Soybean	Present Investigation	-

3.4 EXPERIMENTAL DETAILS:

The experiment was laid out in a simple design consisting of seven irrigation treatments and two replications. The gross plot size was 6 x 3.6 m^2 and net plot size was 5.4 x 2.7 m^2. The spacing was 22.5 x 5 cm. The irrigation treatments were decided on the basis of various IW/CPE ratios as under.

Treatment No.	IW/CPE ratio
T_1	1.0
T_2	0.9
T_3	0.8
T_4	0.7
T_5	0.6
T_6	0.5
T_7	0.4

For all the irrigations, a constant depth of 8 cm was applied. The layout of the experiment is presented in Fig 3.

3.4.1 Field Operations:

Field operations were carried out according to the recommendations for optimum growth for irrigated conditions. The calendar of operations prior to sowing and during the crop growth period is presented in Table 5.

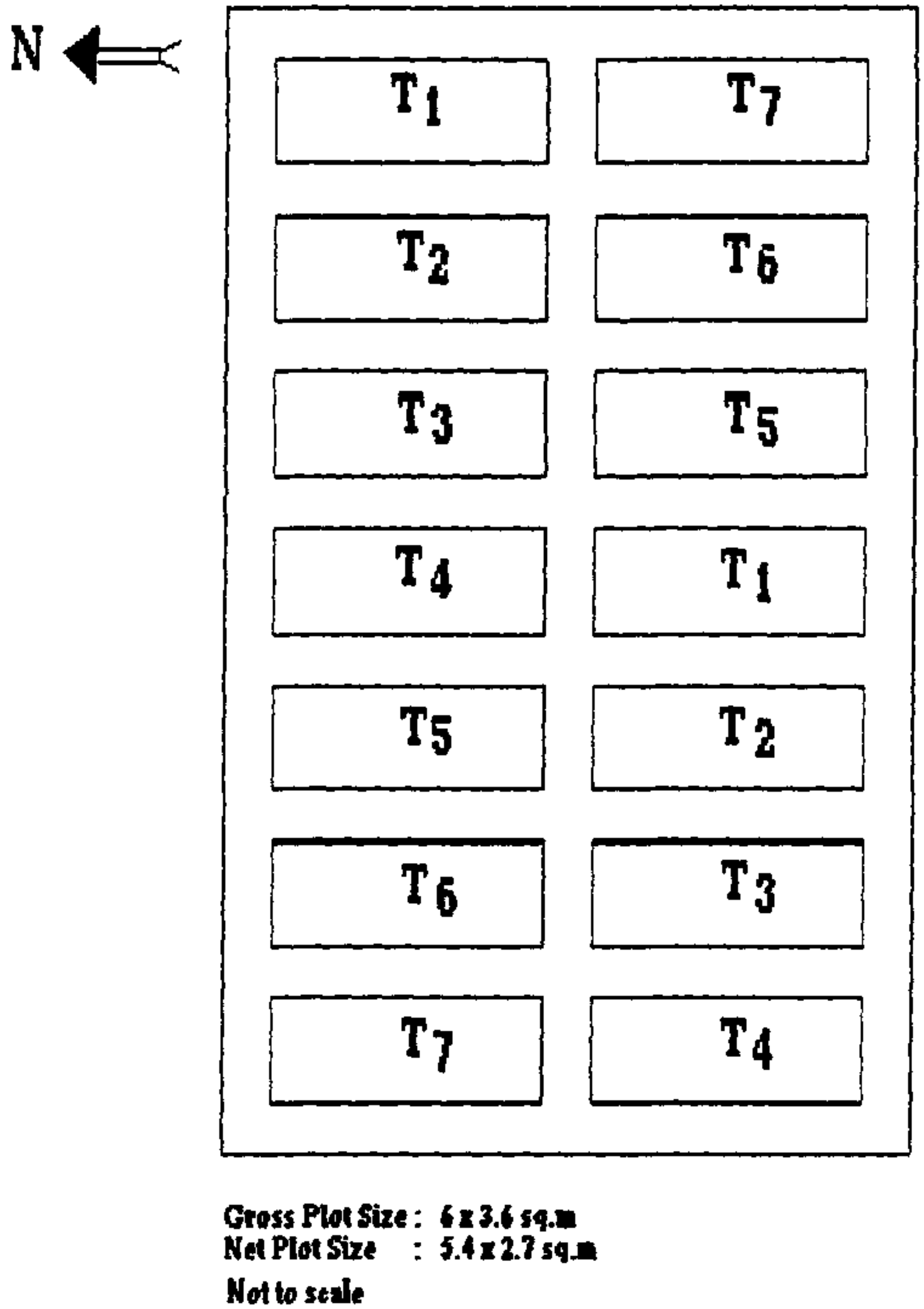

Fig. 3 Plan of layout of experiment, 1989-90

Table 5 Details of the field operations carried out for 1989-90

Sr. No.	Field operation	Implement used	Date of operation
A	Pre-sowing operation		
1.	Ploughing	Iron plough	5 - 11 - 89
2.	Discing	Tractor drawn	6 - 11 - 89
3.	Harrowing	Disc harrow Deccan blade harrow	7 - 11 - 89
4.	Collection of stubble	----	8 - 11 - 89
5.	Preparation of sara for pre-sowing	Sara yantra	9 - 11 - 89
6.	Pre-sowing irrigation	-----	10 - 11 - 89
7.	Harrowing and planking	Deccan blade harrow	14 - 11 - 89
B	Sowing		
1.	Collection of stubble and experimental layout	Tape, Spade, sickle, pegs, etc.	16 - 11 - 89
2.	Sowing and application of fertilizer	-----	16 - 11 - 89
3.	Install black polythene	-----	16 - 11 - 89
4.	Install neutron probe	-----	16 - 11 - 89
5.	Post sowing irrigation	-----	16 - 11 - 89
C	Post Sowing Operations		
1.	Gap filling	-----	24 - 11 - 89
2.	Weeding	Weeding hook	6 - 12 - 89
3.	Irrigation	As per the treatment	
4.	Weeding	Weeding hook	4 - 01 - 89
5.	Harvesting	Sickle	4 - 03 - 89
6.	Threshing	Mogari	10 - 03 - 89

3.4.2 Seed, Sowing and Fertilizer Application:

Seed of H.D. 2189 was mixed with Azotobacter at the rate of 250 gm per 10 kg of seed before sowing. Sowing was done by dibbling method. The row spacing was 22.5 cm. Maximum care was taken to sow the seeds uniformly.

Fertilizer dose of 60 kg N + 60 kg P_2O_5 + 60 kg K_2O per hectare was used for all the treatments. Suphala 15:15:15 was used as the source. The fertilizer dose was uniformly broadcasted before sowing and carefully mixed into the soil.

3.4.3 Gap Filling:

Gap filling for all the treatments was done ten to eleven days after sowing

3.5 APPLICATION OF IRRIGATION WATER:

The channels in the field were lined with black ploythene paper so as to avoid the average losses. The irrigation water was measured with the help of 'V' notch. Each time 1728 litre of water (equivalent to 8 cm depth of water) was given for each plot.

Irrigations were given as per the IW/CPE ratio. The details of the irrigations given are shown in Table 6.

3.6 STUDY OF SOIL MOISTURE:

3.6.1 Soil Moisture Constants:

Single value physical constants of the soil were used for irrigation studies, i.e. field capacity, bulk density and permanent wilting point were determined for different soil layers. The soil layers considered were 0-15 cm; 15-30 cm and 30-45 cm; 45-60 cm, 60-75 cm and 75-90 cm. Table 7 gives the values of soil moisture constants for these layers.

Table 6 Irrigation schedules as per treatments

Treatment No.	IW/CPE ratio	Irrigation received	Days from sowing	Date of irrigation
T_1	80 x 1 ÷ 82.09	1^{st}	19	5-12-89
	80 x 2 ÷ 159.63	2^{nd}	39	25-12-89
	80 x 3 ÷ 242.23	3^{rd}	61	16-01-90
	80 x 4 ÷ 318.73	4^{th}	78	2-02-90
	80 x 5 ÷ 399.63	5^{th}	94	18-02-90
T_2	80 x 1 ÷ 89.72	1^{st}	21	7-12-89
	80 x 2 ÷ 180.53	2^{nd}	46	1-01-90
	80 x 3 ÷ 271.43	3^{rd}	68	23-01-90
	80 x 4 ÷ 362.63	4^{th}	87	11-02-90
T_3	80 x 1 ÷ 102.21	1^{st}	24	10-12-90
	80 x 2 ÷ 201.33	2^{nd}	52	7-01-90
	80 x 3 ÷ 299.43	3^{rd}	74	29-01-90
	80 x 4 ÷ 399.63	4^{th}	94	18-02-90
T_4	80 x 1 ÷ 109.43	1^{st}	26	12-12-90
	80 x 2 - 218.83	2^{nd}	56	11-01-90
	80 x 3 ÷ 331.23	3^{rd}	81	5-02-90
T_5	80 x 1 ÷ 130.23	1^{st}	31	17-12-90
	80 x 2 ÷ 261.13	2^{nd}	66	21-01 90
	80 x 3 ÷ 293.73	3^{rd}	93	17-02-90
T_6	80 x 1 ÷ 159.63	1^{st}	39	25-12-89
	80 x 2 ÷ 318.73	2^{nd}	78	2-02-90
T_7	80 x 1 ÷ 201.33	1^{st}	52	7-01-90
	80 x 2 ÷ 399.83	2^{nd}	94	18-02-90

Table 7 Soil moisture constants of the experimental field

Constants	Soil depth					
	0-15	15-30	30-45	45-60	60-75	75-90
Field capacity (per cent)	37.71	38.91	39.68	40.69	40.50	39.56
Bulk density (gm/cc)	1.06	1.09	1.11	1.12	1.11	1.10
Permanent wilting Point (per cent)	23.70	22.90	22.50	23.50	23.90	23.30

From this table, the average values of these constants were computed as under:

Field capacity	=	39.51 per cent
Permanent wilting point	=	23.30 per cent
Bulk density	=	1.10 gm/cc

3.6.2 Determination of soil moisture:

The soil moisture for 0-15 cm layer were determined by gravimetric method. The soil moisture from 30-90 cm was measured with the help of neutron probe at an interval of 15 cm depth. The soil moisture was recorded just before the irrigation. The counts/sec. were converted into cm/m depth of water by using the following formula:

$$\theta = 0.958 \frac{R}{RW} - 0.12 \times 15$$

Where,

θ	=	Volumetric water content of the soil expressed as a fraction, i.e., volume of water per volume of soil
R	=	Count rate obtained in the soil at the time of observation (counts per seconds)
RW	=	Count rate in pure water (counts per second)

3.6.3 The evapotranspiration (consumptive use) was calculated by the formula:

Evapotranspiration or consumptive use of water was computed as under:

$$ET = K \times 0.8 + \sum_{i=1}^{n} \frac{M1_i - M2_i}{100} \times As_i \times D_i + ER$$

where

ET	=	Evapotranspiration (mm);
K	=	Actual evaporation from two days, or immediately after K^{th} irrigation from open pan evaporation (mm);
n	=	Number of soil layers;
$M1_i$	=	Moisture (%) after 1-2 days since irrigation in i^{th} layer;
$M2_i$	=	Moisture (%) before present irrigation in i^{th} layer;
As_i	=	Bulk density of i^{th} layer (gm cc^{-3});
D_i	=	Soil depth (mm) of i^{th} layer; and
ER	=	Effective rainfall.

This equation was used by Singh et al. (1960 and 1961). The evapotranspiration for the period between two irrigations was worked out with the formula as stated above.

In this formula it was assumed that soils attain field capacity conditions after two days from the day of irrigation.

The cumulative different crop growth stagewise and weekly evapotranspiration was calculated from the graph drawn for cumulative evapotranspiration as per the different IW/CPE ratio.

3.6.4 Potential evapotranspiration (PET):

The PET formula (Penman, 1984) was used for the estimation of potential evapotranspiration.

$$ET = \frac{\frac{P_o}{P} \cdot \frac{\Delta}{\tau} \left[0.75\, R_A \{a + b(n/N)\} - \sigma T_K^4 \{0.56 - 0.079 \sqrt{(ed)}\} \{0.10 + 0.90\, (n/N)\} \right] + 0.26(ea - ed)(1.0 + 0.54\, U)}{\frac{P_o}{P} \frac{\Delta}{\tau} + 1.00}$$

The terms intervening in the formulae and in the working sheets are defined here under and expressed in the following units:

Where,

E_T	=	Estimation of the potential evapotranspiration for a given period, expressed in mm;
P_o	=	Mean atmospheric pressure expressed in millibars at sea level;
P	=	Mean atmospheric pressure expressed in millibars as a function of altitude, for the station where the estimate is calculated;
Δ	=	Rate of change with temperature of the saturation vapour pressure expressed in millibars per degree °C;
τ	=	The psychometric coefficient for the psychrometer with forced ventilation = 0.66;
0.75 & 0.95	=	Factors expressing the reduction in the incoming short wave radiation on the evaporating surfaces and corresponding respectively to an albedo of 0.25 and 0.05;

R_A = Short wave radiation received at the limit of the atmosphere expressed in mm of evaporable water (1 mm = 59 calories) and taking for the solar constant the value of 2.00 cal. cm_{-2} min_{-1};

a & b = Coefficients for the estimation of total radiation from the sunshine duration (see paragraph 2.1);

n = Sunshine duration for the period considered in hours and tenths; and

N = Sunshine duration astronomically possible for the given period.

σT_K^4 = Blackbody radiation expressed in mm of evaporable water for the prevailing air temperature;

ea = Saturation vapour pressure expressed in millibars;

ed = Vapour pressure for the period under consideration expressed in millibars;

T°C = Air temperature measured in the meteorological shelter and expressed in degrees Celsius;

$T_K°$ = Air temperature expressed in degrees Kelvin where $T_K° = T°C + 273$;

$U_{m/s}$ = Mean wind speed at an elevation of 2 m for the given period and expressed in m per second.

3.6.5 Vapour Pressure deficit (V.P.D.):

The daily dry bulb and wet bulb temperature was recorded in agrometeorological observatory and by using the psychometric chart the vapour pressure deficit was calculated as follows.

Vapour pressure deficit = saturation vapour pressure − actual vapour pressure

3.6.6 Crop Coefficient (Kc):

The crop coefficient was calculated using the formula given below:

$$\text{Crop coefficient} = \frac{\text{Actual evapotranspiration}}{\text{Potential evapotranspiration}}$$

3.6.7 Water Use Efficiency (WUE):

The water use efficiency based on grain yield and total dry matter was determined by following formulae:

I.]

$$\text{Water use efficiency} = \frac{\text{Grain yield}}{\text{Actual evapotranspiration}} \quad \text{kg/ha-mm}$$

II.]

$$\text{Water use efficiency} = \frac{\text{Total dry matter}}{\text{Actual evapotranspiration}} \quad \text{kg/ha-mm}$$

3.7 COLLECTION OF DATA:

3.7.1 Initial and Final Plant Count:

All the plants in one square meter of area were counted for the initial and final plant count.

3.7.2 Growth Studies:

The observations for the growth studies were recorded on five plants randomly selected from each treatment. A label with tag was loosely tied to the mother shoot and wooden pegs were fixed near the observational plants. Observations were recorded as follows.

3.7.2.1 Plant height:

The length of the main shoot of the five randomly selected plants was measured from the ground level to the base of last opened leaf up to the stage of earhead emergence. After this period, shoot length was measured from the ground level up to the base of the earhead. The observation were taken at the different phenological stages.

3.7.2.2 Number of functional leaves per plant:

The entirely green leaves per plant were counted. Besides, the leaves of which were less than half of its area were dried and were counted as functional leaves. But the leaves which were more than half of its area were excluded. The number of functional leaves was counted on the observational plants only.

3.7.2.3 Leaf area per plant:

Per plant leaf area of functional leaves was recorded during the growth period. Five randomly selected plants for dry matter study were used for recording leaf area. The leaves from each tiller were removed and with the help of leaf area meter the leaf area was calculated. The observations were taken at the different phenological stages.

3.7.2.4 Leaf area index (LAI):

Leaf area index was calculated by the formula as follows.

$$\text{Leaf area index} = \frac{\text{leaf area of the plant}}{\text{Area allotted to that plant}}$$

The observations were taken at different phenological stages.

3.7.2.5 Number of tillers per plant:

Tillering is a very important character in wheat which indicates growth. The total number of tillers per plant was counted to study the potentiality of the plant under the various treatments. The observations on this character on the observational plants were taken at tillering, jointing, flowering, milk and physiological maturity stages.

3.7.2.6 Dry matter per plant:

For the drymatter measurements, five plants were randomly selected (same plants which were selected for leaf area) from each treatment. The material was chopped, dried in sun and then it was dried in a hot air oven at about 70°C. After weighing the material, dry matter per plant was calculated.

3.7.2.7 Date of physiological maturity:

The same plants which were selected for shoot length studies were also used for these observations. The date (days after sowing) on which 50 per cent or more than 50 per cent plants were yellowed was recorded as the date of maturity.

3.7.3 Yield Contributing Characters:

3.7.3.1 Length of earhead:

The earheads from the five observational plants were used for the measurement of length of earhead. It was measured from base to the tip of the last spikelet of the earhead at harvest.

3.7.3.2 Number of spikelets per earhead:

The number of spikelets was counted from the five observational plants. Only the functional spikelets were considered for counting the number of spikelets per earhead.

3.7.3.3 Number of grains per earhead:

The number of grains per earhead was worked out by counting the number of grains per earhead on the observational plants.

3.7.3.4 Grain weight per earhead:

The earheads of the observational plants were threshed, weighed and grain weight per earhead was calculated.

3.7.3.5 Weight of thousand grains:

A sample of thousand grains from the total grain produced from each plot was taken at random and its weight was recorded.

3.7.4 Yield Data:

3.7.4.1 Total dry matter produce per hectare:

The total dry matter produce harvested from the net plot of each of the treatments was tied in bundles, dried in the sun and weighed until a constant weight was achieved then it was recorded. From these data, total dry matter in quintals per hectare was computed.

3.7.4.2 Grain yield per hectare:

The total produce from each net plot of each treatment was threshed separately and cleaned to obtain grain. The grain weight was then recorded and was calculated in quintals per hectare.

3.7.4.3 Straw yield per hectare:

This was recorded by finding out the difference between total dry matter produced and total grain weight from each net plot and then the figure was computed in quintals per hectare.

3.7.4.4 Grain to straw ratio:

Ratio of grain to straw was calculated by dividing the weight of grain by the weight of straw.

3.8 HARVEST INDEX:

The harvest index - was calculated by using the formula as under:

$$\text{Harvest index} = \frac{\text{Grain Yield}}{\text{Total dry matter}} \times 100$$

3.9 DATA COLLECTION FROM OBSERVATORY:

The meteorological data viz.; maximum and minimum air temperature (°C), dry bulb and wet bulb temperature (°C), bright sunshine (hours), wind speed (KMPH), open pan evaporation (mm), rainfall (mm) etc. were collected from the central Agricultural Meteorological observatory located at the college of Agricultural farm Pune-5. The experimental field was just 400 m away from the observatory.

3.10 DETAILS OF THE INSTRUMENTS USED:

Neutron probe was used for the measurement of soil moisture and leaf area meter was used for the measurement of leaf area. The details of these instruments are as follows.

3.10.1 Neutron Probe:

DIDCOT soil moisture probe was used to monitor the soil moisture. The soil moisture probe is illustrated in Plate 1.

Major components of the system are the probe, probe carrier, rate scaler and connecting cable.

Probe carrier:

It is made up of PVC pipe which holds the probe inside and the rate scaler at the top. It has a socket at its base through which it is fitted on the access tube so that the probe may be lowered directly from the carrier into the tube.

Rate scaler:

It is a short computing unit attached through hinges to the upper end of the carrier. It can be detached when not in use. The rate scaler is connected to the cable by a socket provided at its base. Rate scaler performs and display calculations. It also stores data and software. The liquid crystal displays mean count rate at the conclusion of present counting time, in counts per second.

Connecting cable:

It connects the rate scaler to the probe. It being 5 m long, allows soil moisture monitoring up to the depth of 4 m. While the probe is lowered in the access tube, the moving cable operates depth counter and the clamping of cable holds probe operates with an input supply of 13 V acting through the cable and 11 V pulses are returned to the rate scaler through the same cable.

PLATE 1 NEUTRON PROBE

PLATE 2 LEAF AREA METER

Probe:

It consists of a stainless steel cylinder of the size of 38 mm in diameter and 750 mm in length. The cylinder is marked with a line at mid-plane of the source. The internal layout of probe is shown in Fig. 5

Probe contains Americium Beryllium, a fast neutron source. The Boron Trifluoride (BF_3) is positioned at the mid point of sensitive tube. Technical specifications of soil moisture probe are presented in Fig. 5

Working principles:

When the probe is lowered in the access tube at a desired depth, fast neutron source Am - Be emits fast neutrons in the soil. The sphere of influence of neutrons has 30 cm diameter. The neutrons collide with the hydrogen atoms present in soil water and get scattered. The slowed neutrons are known as thermal neutrons. The cloud of thermal neutrons is generated within the soil around the probe. The density of cloud is largely a function of water content of the soil. The density of cloud of thermal neutron is sensed by BF_3 in the probe. The electrical pulse produced by BF_3 is amplified and transmitted to the rate scaler through the cable. The rate scaler displays the pulses in terms of counts per second. These counts per second are subsequently converted into volumetric soil water with the help of given equations. The parameters of two equations are different for different types of soil.

3.10.2 Leaf Area Meter:

Leaf are at six growth stages was measured with the help of LI-3000 portable leaf area meter. LI-3000 leaf area meter has two major components viz., scanning head and readout console. The system is presented in Plate 2.

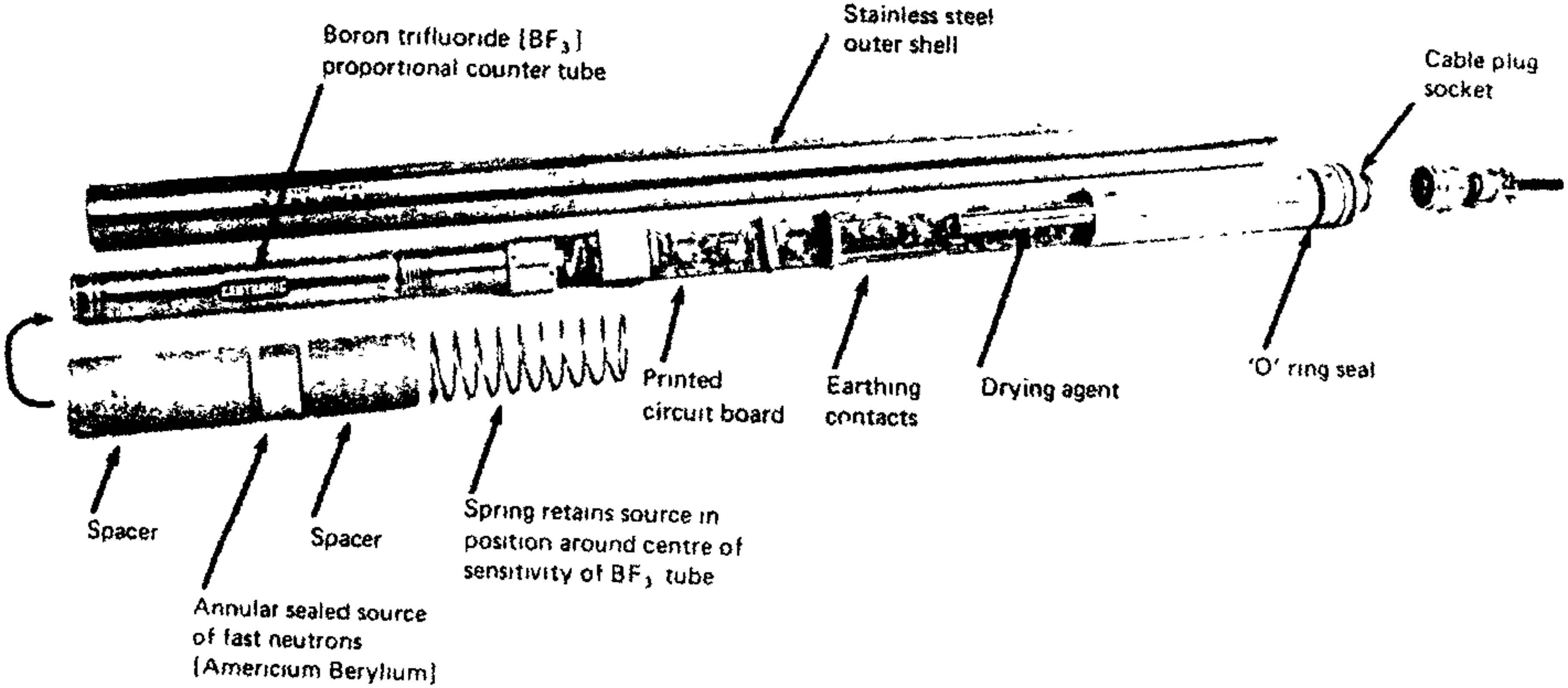

Fig.5 Inner contents of the probe

Readout console:

It is a computing and display unit. The console is connected to the scanning head by 3000 A-03 interface cable. The readout console has following features. Displays leaf length, average width, maximum width and leaf area. In addition to measurement of leaf area, other mathematical operations like summation, averaging etc. are carried out after specified user commands. The readings are stored and later retrieved through a computer or printer which can be connected to the console through Rs - 232 interface.

Scanning head:

The function of the LI - 3000 portable area meter is to use electronic method to stimulate a grid pattern on the leaf. The scanning head uses a row of 128 narrow band red light emitting diodes (LEDS) which are spaced at 1 mm interval, to examine 128 grid cells across the width of leaf. The LEDS are located along a line at 0.62 cm from the outer edge of upper section of scanning head. On the basal half of scanning head lens photodiode system is located, which responds only to the pulsed LEDS. With the help of length encoding cord, after each 1 mm of cord travel a new set of scans is generated. The details of scanning head is shown in Fig. 5

Working principle:

When the leaf is passed through the scanning head , according to the width of leaf in each set of scan number of LEDS are blocked and sensed by lens photodiode system. According to number of scanning required, the length of the leaf is measured. From the average width and length of leaf, the leaf area is calculated and displayed on the console.

4. RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

In this chapter, attempts are made to present and discuss the results of this investigation and to integrate the effects of the various treatments on the functional characters of crop and soil moisture studies leading to final expression of yield as a result of the various irrigation treatments.

4.1 SOILS:

From the mechanical analysis of the soil of the experimental field (Table 2) it was observed that the soil was clayey in texture. It was well drained, medium black, fairly deep and suitable for raising a crop of wheat.

4.2 WEATHER:

It will be evident from Table 4 that there were no rains during the crop growth period. Weather during the season was favourable for wheat crop under irrigated conditions.

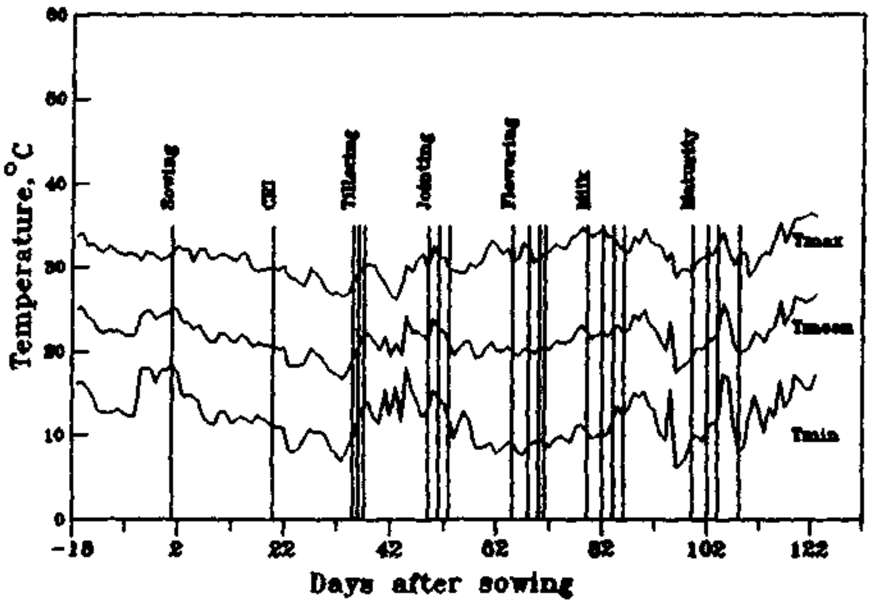

Fig. 6 Maximum, minimum and mean temperature and crop growth stages during the experimental period

The Fig. 6 shows the maximum temperature, minimum temperature and average temperature of the crop growth period. The minimum temperature was always higher than 5°c. Similarly daily mean temperature was higher than 15°c, i.e., the optimum temperature for the crop growth of wheat crop. For tillering stage, the favourable temperatures are greater than 20°c. However, in a week prior to tillering stage temperature varied between 16.7° and 19.6°c. It might have delayed the tillering stage by one to two days. For ripening stage, temperature should be more than 18°c where as it actually ranged between 22.8° and 23.5°c. Therefore, in total, temperature conditions were favourable for wheat growth.

Sowing of the crop was done on the November 16th 1989 which is a normal sowing time for wheat crop. Pre-sowing irrigation was given on the November 10th 1989. Immediately after sowing, a common post sowing irrigation was given to all the plots to ensure uniform germination. Subsequent irrigations were given as per IW/CPE ratio for the various treatments as given in Table 8.

Table 8. Irrigation dates and period of intervals (days) between irrigation given as per IW/CPE ratio

Treat-ment	IW/CPE ratio	Irrigation number										Total irrigations
		1st		2nd		3rd		4th		5th		
		Date	period	Date	period	Date	period	Date	period	Date	period	
T_1	1.0	4-12-89	19	24-12-89	20	15-01-90	22	1-02-90	17	17-02-90	16	5
T_2	0.9	6-12-89	21	31-12-89	25	23-01-90	23	10-12-90	18	-	-	4
T_3	0.8	9-12-89	24	6-01-90	28	27-01-90	21	16-02-90	20	-	-	4
T_4	0.7	11-12-89	26	10-01-90	30	4-02-90	25	-	-	-	-	3
T_5	0.6	16-12-89	31	20-01-90	35	16-12-90	27	-	-	-	-	3
T_6	0.5	24-12-89	39	1-02-90	39	-	-	-	-	-	-	2
T_7	0.4	6-01-90	52	17-02-90	42	-	-	-	-	-	-	2

4.3 NUMBER OF DAYS FOR PHYSIOLOGICAL GROWTH STAGES AND IRRIGATIONS GIVEN AFTER SOWING:

The data regarding number of days required for attaining physiological growth stages viz; crown root initiation, tillering, jointing, flowering, milk and physiological maturity and also of the number of days required for giving the irrigation after sowing for different treatments are presented in Tables 9 and 10 and are graphically shown in Figs. 7 and 8, respectively.

Table 9 Number of days from sowing to attainment of various physiological growth stages of irrigation treatments

Treatment No.	T_1	T_2	T_3	T_4	T_5	T_6	T_7
IW/CPE ratio	1	0.9	0.8	0.7	0.6	0.5	0.4
physiological growth stages	Day from sowing to physiological growth stages						
Crown root initiation	20	20	20	20	20	20	20
Tillering	37	37	37	36	36	35	35
Jointing	53	53	53	51	51	49	49
Flowering	71	70	70	68	68	65	65
Milk	86	84	84	82	82	79	79
Physiological maturity	108	104	104	102	102	99	99

From the data, it would be observed that all the treatments attained crown root initiation on the 20^{th} day after sowing. The number of days required to attain the crown root initiation stage were the same for all the seven treatments because all the treatments were given the post sowing irrigation just after the sowing. The tillering stage was attained in the treatments with IW/CPE of 1.0,

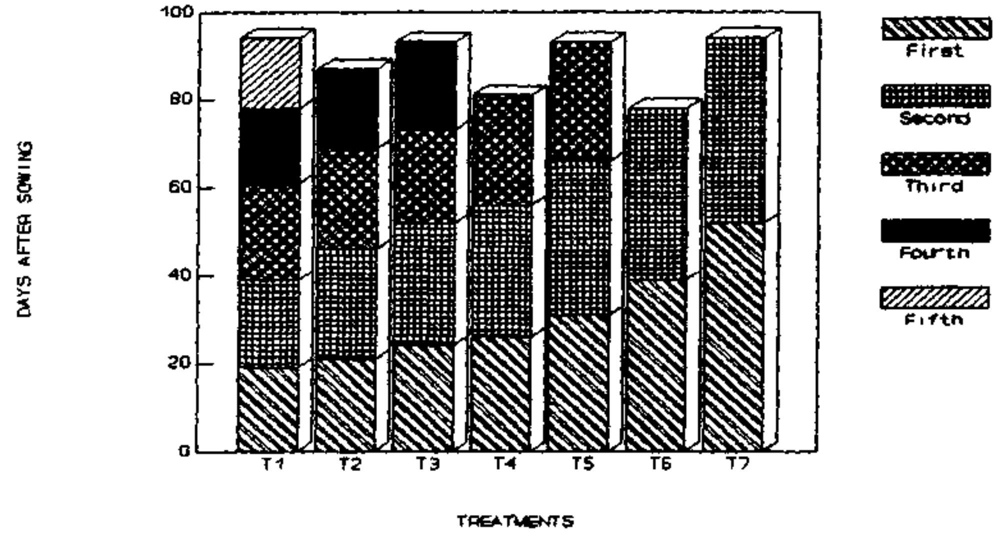

Fig. 7 Number of days after sowing at which irrigation was given as per IW/CPE ratio

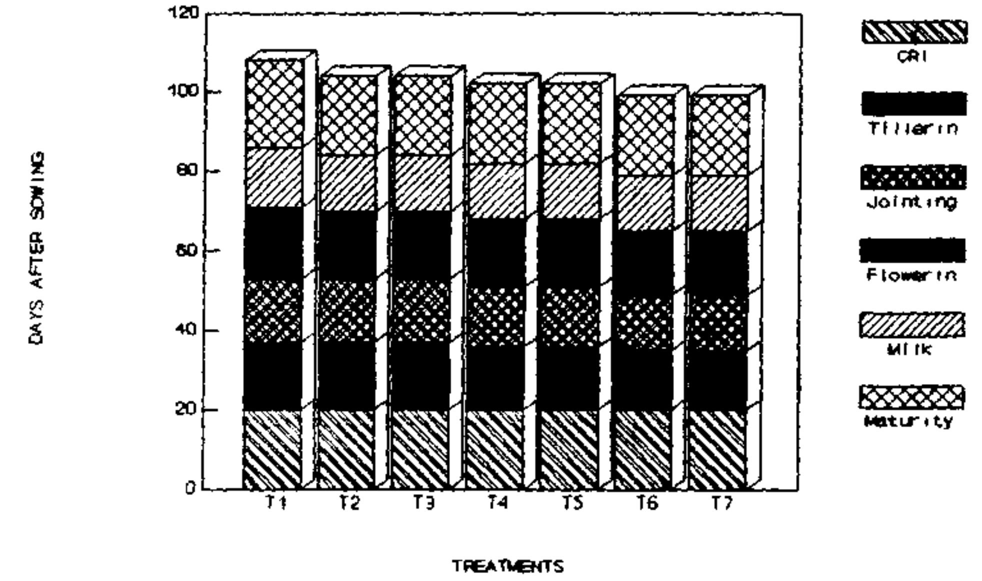

Fig. 8 Number of days after sowing to attainment of various physiological growth stages

0.9 and 0.8 on the 37th day. In the treatments with IW/CPE of 0.7 and 0.6 on the 36th and in the treatments with IW/CPE of 0.5 and 0.4 on the 35th day after sowing. The tillering stage in the treatments with IW/CPE of 1.0, 0.9 and 0.8 was attained late because they received the irrigation earlier than did the treatments with IW/CPE of 0.7, 0.6, 0.5 and 0.4.

Treatments with IW/CPE of 1.0, 0.9 and 0.8 attained jointing stage on the 53rd day after sowing because they received irrigations one after the other. The treatments with IW/CPE of 0.7 and 0.6 attained this stage on the 51st day while the treatment with IW/CPE of 0.5 and 0.4 attained it on the 49th day. The treatment with IW/CPE of 1.0 attained the flowering stage on the 71st day after sowing treatments with IW/CPE of 0.9 and 0.8 attained this stage on the 70th day and IW/CPE of 0.7 and 0.6 attained it on the 68th day. The treatments with IW/CPE of 0.5 and 0.4 attained it on the 65th day after sowing. Obviously, the treatments with IW/CPE of 0.5 and 0.4 experienced water stress and attained the flowering stage earlier.

Table 10 **Number of days from sowing at which irrigation was given as per IW/CPE ratio for irrigation treatments**

Number of irrigations		1st	2nd	3rd	4th	5th	Total irriga-tion
Treatment	IW/CPE ratio	Day of application of irrigation					
T_1	1.0	19	39	61	78	94	5
T^2	0.9	21	46	69	87	-	4
T_3	0.8	24	52	73	93	-	4
T_4	0.7	26	56	81	-	-	3
T_5	0.6	31	66	93	-	-	3
T_6	0.5	39	78	-	-	-	2
T_7	0.4	52	94	-	-	-	2

Milk stage came in IW/CPE of 1.0 on the 86th after sowing, while in IW/CPE of 0.9 and 0.8 it occurred on 84th day. In IW/CPE of 0.7 and 0.6 it occurred on the 82nd day and IW/CPE of 0.5 and 0.4 it occurred on the 79th day after sowing. This was because up to milk stage IW/CPE of 1.0 received four irrigations. IW/CPE of 0.9, 0.8 and 0.7 received three irrigations. IW/CPE of 0.6 and 0.5 received two irrigations and IW/CPE of 0.4 received only one irrigation. The Treatments with IW/CPE of 0.6 and 0.5 though received two irrigations up to milk stage IW/CPE of 0.5 attained milk stage three days earlier than IW/CPE of 0.6 because it received second irrigation very late i.e. on the 78th day. Treatments with IW/CPE of 0.5 and 0.4 matured on the 99th day i.e. earlier than all the other treatments. This was because IW/CPE of 0.5 and 0.4 experienced water stress. IW/CPE of 1.0 matured on the 108th day i.e. later than all the treatments.

These results indicate that increase in the number of irrigations increased the number of days to attain different physiological growth stages. This might be due to the fact that when less number of irrigations was given, water stress occured during the crop growth period and plants tried to hasten their growth stages so as to complete their life cycle as earlier as possible.

4.4 SOIL MOISTURE STUDIES:

The data were taken from the layers of 0-15, 15-30, 30-45, 45-60, 60-75 and 75-90 cm. This data were recorded for the different irrigation treatments as per IW/CPE ratio.

The treatment with IW/CPE of 1.0 was given five irrigations. The irrigations were given on the 19th, 39th, 61st, 78th and 94th day after sowing. The actual values of IW/CPE were 80 x 1/82.09, 80 x 2/159.63, 80 x 3/242.23, 80 x 4/318.73 and 80 x 5/399.63 = 1. The average soil moisture readings on the day before these irrigations were 34.95, 33.90, 29.95, 31.06 and 32.60 cm m^{-1}. The soil moisture of physiological maturity was 36.49 cm m^{-1}, respectively. The soil moisture was initially high i.e. on the 19th day after sowing, then it went on decreasing up to the 61st day and after that it was increased at the physiological maturity stage.

The treatment with IW/CPE of 0.9 was given four irrigations. The irrigations were given on the 21st, 46th, 69th and 87th day, respectively after sowing. The actual values of IW/CPE were 80 x 1/89.72, 80 x 2/180.53, 80 x 3/271.43 and 80 x 4/362.63 = 0.9. The average soil moisture readings immediately before these irrigations were 34.40, 32.28, 29.15 and 31.60 cm m^{-1}, respectively.

		Depth of soil layer in cm	Days after sowing											
			52		94		99							
			c/sec	cm/m	c/sec	cm/m	c/sec	cm/m						
		0-15*	-	1.39	-	1.32	-	3.40	-	-	-	-	-	-
		15-30	280	3.99	275	3.92	451	6.54	-	-	-	-	-	-
		30-45	368	5.31	366	5.28	484	7.03	-	-	-	-	-	-
T_7	0.4	45-60	411	5.95	415	6.01	498	7.24	-	-	-	-	-	-
		60-75	436	6.32	432	6.26	503	7.32	-	-	-	-	-	-
		75-90	474	6.39	472	6.86	510	7.42	-	-	-	-	-	-
				29.85		29.70		38.95	-	-	-	-	-	

* The soil moisture for 0-15 cm layer were determined by gravimetric method.

The treatment with IW/CPE of 1.0 was given five irrigations. The irrigations were given on the 19th, 39th, 61st, 78th and 94th day after sowing. The actual values of IW/CPE were 80 x 1/82.09, 80 x 2/159.63, 80 x 3/242.23, 80 x 4/318.73 and 80 x 5/399.63 = 1. The average soil moisture readings on the day before these irrigations were 34.95, 33.90, 29.95, 31.06 and 32.60 cm m^{-1}. The soil moisture of physiological maturity was 36.49 cm m^{-1}, respectively. The soil moisture was initially high i.e. on the 19th day after sowing, then it went on decreasing up to the 61st day and after that it was increased at the physiological maturity stage.

The treatment with IW/CPE of 0.9 was given four irrigations. The irrigations were given on the 21st, 46th, 69th and 87th day, respectively after sowing. The actual values of IW/CPE were 80 x 1/89.72, 80 x 2/180.53, 80 x 3/271.43 and 80 x 4/362.63 = 0.9. The average soil moisture readings immediately before these irrigations were 34.40, 32.28, 29.15 and 31.60 cm m^{-1}, respectively.

The soil moisture at the physiological maturity was 35.87 cm m^{-1}. Soil moisture was initially high up to the 21st day, it went on decreasing up to the 69th day and then it was increased at the physiological maturity stage.

The treatment with IW/CPE of 0.8 was given four irrigations. The irrigations were given on the 24th, 52nd, 73rd and 93rd day, respectively after sowing. The actual values of IW/CPE were 80 x 1/102.21, 80 x 2/210.33, 80 x 3/299.43, 80 x 4/399.23 = 0.8, respectively. The average soil moisture readings immediately before these irrigations were 33.64, 32.11, 30.21, 31.17 cm m^{-1}, respectively. The soil moisture at the physiological maturity stage was 38.05 cm m^{-1}. Soil moisture was initially high up to the 24th day, then it went on decreasing up to the 73rd after sowing and afterwards it was increased at the physiological maturity stage.

The treatment with IW/CPE of 0.7 was given three irrigations. The irrigations were given on the 26th, 56th and 81st day, respectively after sowing. The actual values of IW/CPE were 80 x 1/109.43, 80 x 2/218.83 and 80 x 3/331.73 = 0.7, respectively. The average soil moisture readings before these irrigations were 33.38, 31.14, 29.66 cm m^{-1}, respectively. The soil moisture at the physiological maturity stage was 35.59 cm m^{-1}. Soil moisture was initially high up to the 26th after sowing, then it went on decreasing up to the 81st and then again it increased at physiological maturity stage.

The treatment with IW/CPE of 0.6 was given three irrigations. The irrigations were given on the 31st, 66th and 93rd day, respectively after sowing. The actual values of IW/CPE were 80 x 1/130.23, 80 x 2/261.13, 80 x 3/393.73 = 0.6, respectively. The average soil moisture before these irrigations were 32.52, 22.90, 31.90 cm m^{-1}, respectively. The soil moisture at physiological maturity stage was 38.10 cm m^{-1}. Soil moisture was initially high up to the 31st day, then it went on decreasing up to the 66[th] day and it again increased at physiological maturity stage.

The treatment with IW/CPE of 0.5 was given to irrigations. The irrigations were given on the 39[th] and 78[th] day, respectively after sowing. The actual values of IW/CPE were 80 x 1/159.63, 80 x 2/318.73 = 0.5, respectively. The average soil moisture before these irrigations were 31.60 and 29.65 cm m^{-1}, respectively.

The soil moisture at physiological maturity stage was 35.50 cm m^{-1}. The soil moisture was initially high up to the 39[th] day after sowing, then it went on decreasing up to 78[th] day and increased at physiological maturity stage.

The treatment with IW/CPE of 0.4 was given to irrigations. The irrigations were given on the 52[nd] and 94[th] day, respectively after sowing. The actual values of IW/CPE were 80 x 1 / 201.33 and 80 x 2/399.63 = 0.4, respectively. The average soil moisture before these irrigations were 29.85 and 29.70 cm m^{-1}, respectively. The soil moisture at physiological maturity stage was 38.95 cm m^{-1}. Soil moisture was initially high then it went on decreasing and again it was increased at physiological maturity stage.

In all the treatments the soil moisture was initially high because the initially the roots were under development due to which the absorption of water by the roots was less. Also the number of leaves and leaf area was less due to which loss of water through transpiration was less, hence evapotranspiration losses were minimum. As the crop was in the active growth stage, the number of leaves and leaf area increased. Also the roots were well developed due to which absorption of water by the roots from soil and loss of water from leaves was more. Hence there was maximum evapotranspiration. At physiological maturity the leaves had senescensed and effective leaf area was decreased resulting in less evapotranspiration and more soil moisture.

4.5 CUMULATIVE EVAPOTRANSPIRATION (ET) AS PER IW/CPE RATIO FOR IRRIGATION TREATMENTS:

Evapotranspiration of wheat crop was determined on the basis of soil moisture readings recorded up to the 90 cm depth with the help of neutron probe just before each irrigation and finally at the physiological maturity stage.

The data on evapotranspiration as per IW/CPE ratio and leaf area index as per different growth stages are presented in Table 12. Fig. 9 shows the combined graph of cumulative evapotranspiration for all th seven treatment as per IW/CPE ratio.

It would be obvious from the data that cumulative evapotranspiration was the highest in the treatment with IW/CPE of 1.0 and the lowest in IW/CPE of 0.4. The evapotranspiration values of the other treatment were in between the above two.

Treatment with IW/CPE of 1.0:

It would be clear from the data in the Table 13a that IW/CPE of 1.0 was given five irrigations during the crop growth period. Fig. 10a shows cumulative evapotranspiration as per IW/CPE ratio and physiological growth stagewise leaf area index.

The evapotranspiration in IW/CPE of 1.0 was initially low, i.e. 53.9 mm from sowing to the 19^{th} day. The average daily ET during this period was 2.84 mm. It was because the crop was in the age of crown root initiation. The crop had not produced more number of leaves and hence had less leaf area. Because of less leaf area, radiation intercepted was less and net energy available for loss of water to transpiration was less. The absorption of water by the root was also less because they were under development. Due to this, the transpiration and in turn the evapotranspiration, was less.

Table 12. **Cumulative and particular period evapotranspiration as per IW/CPE ratio for irrigation treatments**

Treatment	IW/ CPE ratio	No. of irrigations	Days from sowing	Period ET (mm)	Cumulative ET (mm)	Actual days for period	ET per day (mm)
1	2	3	4	5	6	7	8
			19	53.9	53.9	19	2.84
			39	63.7	117.6	20	3.19
			61	102.6	220.2	22	4.66
T_1	1.0	5	78	90.2	310.4	17	5.31
			94	77.9	388.3	16	4.87
			108	44.3	**432.6**	14	3.69
			21	59.4	59.4	21	2.83
			46	80.3	139.7	25	3.21
T_2	0.9	4	69	109.6	249.3	23	4.77
			87	91.1	340.4	18	5.06
			104	45.9	**386.3**	17	2.65
			24	67.0	67.0	24	2.79
			52	81.2	148.2	28	2.90
T_3	0.8	4	73	102.1	250.3	21	4.19
			93	93.5	343.8	20	4.68
			104	28.7	**372.5**	11	3.19

(Continued ...)

Table 12 (Continued ...)

Treatment	IW/ CPE ratio	No. of irrigations	Days from sowing	Period ET (mm)	Cumulative ET (mm)	Actual days for period	ET per day (mm)
1	2	3	4	5	6	7	8
T_4	0.7	3	26	69.6	69.6	26	2.68
			56	91.4	161.0	30	3.05
			81	106.1	267.1	25	4.24
			102	49.1	**316.2**	21	2.14
T_5	0.6	3	31	78.2	78.2	31	2.52
			66	104.4	182.6	35	2.98
			93	86.2	269.0	27	3.20
			102	27.2	296.2	09	3.02
T_6	0.5	2	39	87.40	87.4	39	2.24
			78	102.6	190.0	39	2.63
			99	48.9	**238.9**	21	2.45
T_7	0.4	2	52	104.9	104.9	52	2.02
			94	107.2	212.1	42	2.50
			99	19.7	**231.8**	05	4.93

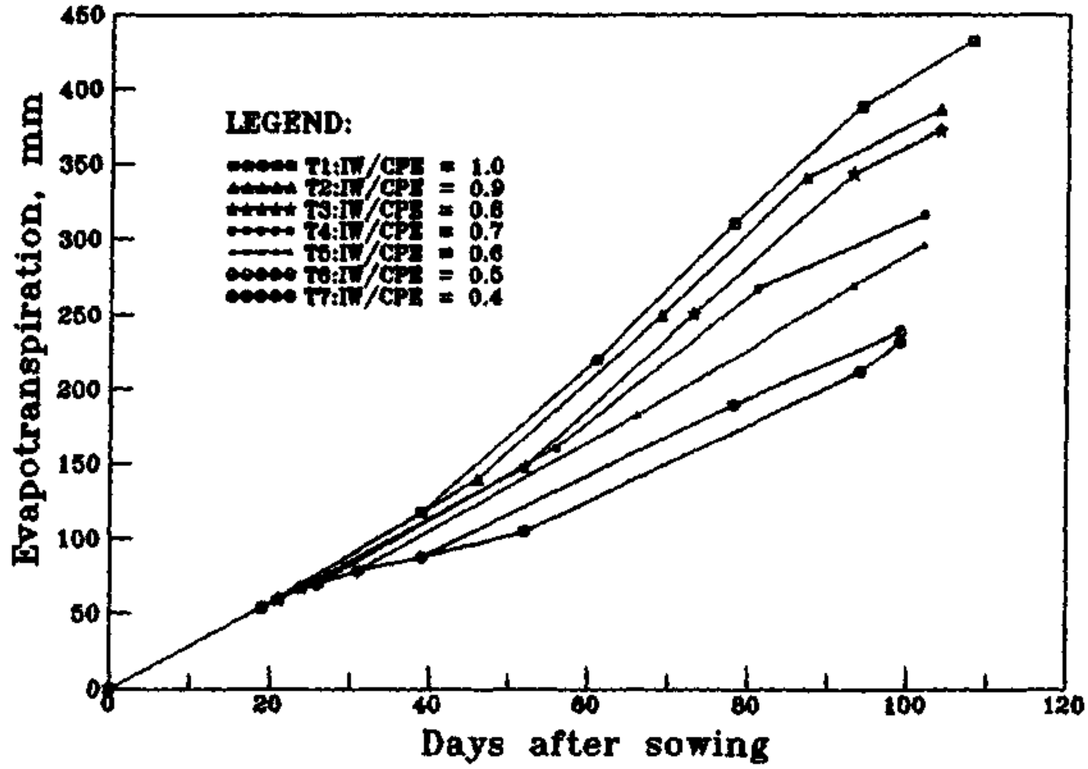

Fig. 9 Combine graph of ET (mm) as per IW/CPE ratio for irrigation treatments

From the 20th to 39th day after, evapotranspiration was 63.7 mm. The average daily ET during this period was 3.19 mm. This treatment attained the tillering stage after 37 days from sowing. There was an increase in the leaf number and hene leaf area which resulted in more leaf area index. Hence, during this period, transpiration was more. As a result, the evapotranspiration was higher as compared to that at the initial period.

From the 40th to 61st day the evapotranspiration was 102.6 mm. The average daily ET during this period was 4.66 mm. The crop had attained the jointing stage on the 53rd day and had the number of leaves and leaf area was more. The energy intercepted was more and net energy available for transpiration was increased. Also the roots being well developed, the absorption of water by them was more. Hence the total evapotranspiration was high.

Table 13a **Cumulative ET as per IW/CPE ratio and physiological growth stagewise LAI for treatment with IW/CPE of 1.0**

Treatment No.	IW/CPE ratio	Observation day	ET (mm)	PGS day	LAI
T_1	1.0	19	53.9	20	0.288
		39	117.6	37	1.379
		61	220.2	53	2.099
		78	310.4	71	1.619
		94	388.3	86	1.107
		108	432.6	108	0.306

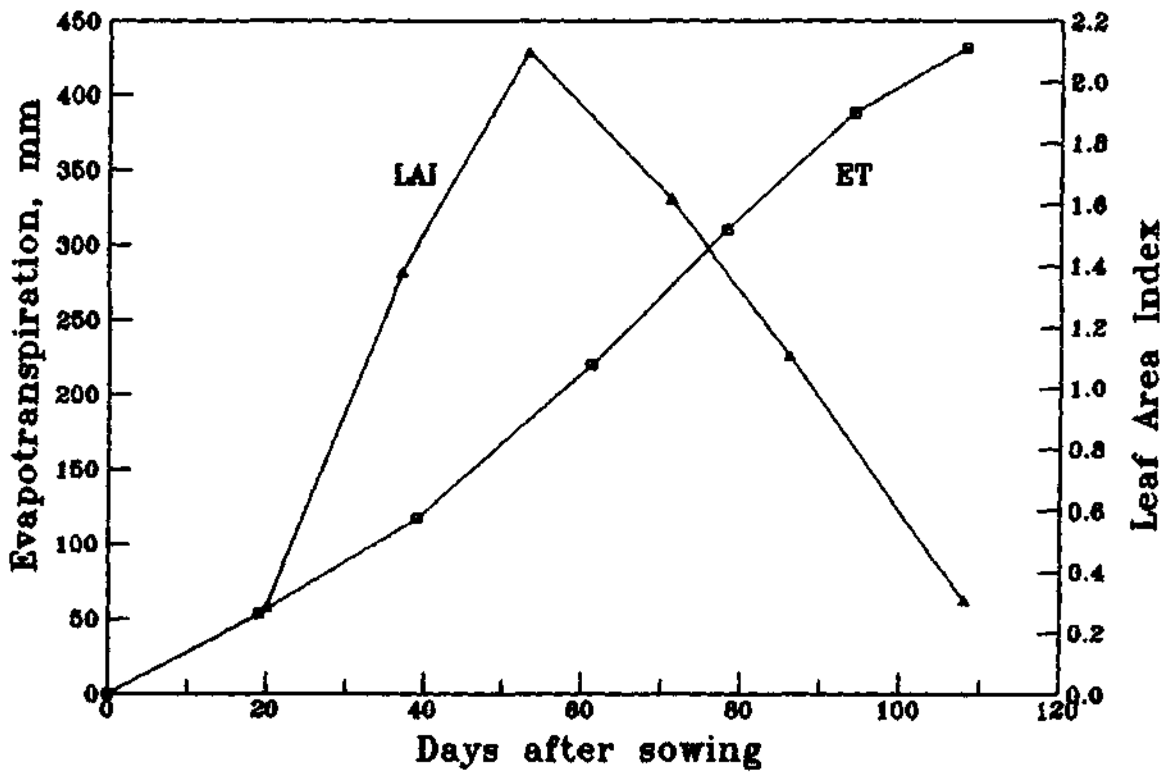

Fig. 10a **Cumulative ET (mm) as per IW/CPE ratio and LAI as per physiological growth stages of the treatment with IW/CPE of 1.0**

From the 62nd to 78th day, the total evapotranspiration was 90.2 mm. The average daily ET was 5.31 mm which was the highest during the crop growth period. This might be for the reason that the crop had attained flowering stage and third irrigation was given during this period.

From the 79th to 94th day, the evapotranspiration was 77.9 mm and the average ET per day was 4.87 mm. There was a slight reduction in the average daily ET during this period because the crop had completed the milk stage and leaf senescence had started resulting in decrease in effective leaf area.

From the 95th day to 108th day, the evapotranspiration was 44.3 mm and average ET per day was 3.69 mm showing decreasing trend. This might be due to the fact that the crop was approaching the physiological maturity stage, thereby leaves had senescensed and effective leaf area was decreased.

The total evapotranspiration during the entire growth period for the treatment with IW/CPE of 1.0 was 432.6 mm.

Thus, in general the evapotranspiration was initially low, then it increased up to the 78th day after sowing and finally decreased up to physiological maturity stage.

Treatment with IW/CPE of 0.9:

The data from the Table 13b show that the IW/CPE of 0.9 was given four irrigations during the crop growth period.

Fig. 10b shows cumulative evapotranspiration as per IW/CPE ratio and physiological growth stage wise leaf area index.

The evapotranspiration was initially low, i.e. 59.4 mm from sowing to the 21st day after sowing and average ET per day was 2.83 mm. It was because the crop attained only crown root initiation stage. The leaves were small and less in number resulting in less leaf area due to which the intercepted radiation was less and net energy available for loss of water through transpiration was less.

Besides, the absorption of water by roots was less due to underdevelopment of roots.

From the 22nd to 46th day, the evapotranspiration was 80.3 mm and average ET per day was 3.21 mm. The crop had attained the tillering stage. The number of leaves was more than the crown root initiation stage and the transpiration was more. Due to this, the ET was more as compared to that in the initial period.

From the 47th to 69th day, the evapotranspiration was 109.6 mm. Average ET per day was 4.77 mm. The crop had attained the jointing stage and was approaching the flowering stage during this period. More number of leaves and leaf area was achieved due to which the energy intercepted was more and net energy available for transpiration increased. Also the absorption of water by the roots was more because they were well developed.

From 70th to 87th day, the evapotranspiration was 91.1 mm. The average daily ET was 5.06 mm, which was highest among the crop growth period. This was because of the fact that the crop had attained the milk stage and was given third irrigation during this period.

From 88th to 104th day, the evapotranspiration was 45.9 mm. The average daily ET was 2.65 mm. This might be due to the fact that the crop was approaching the physiological maturity and the water need of the crop was less because the senescence of leaves causes reduced leaf area thereby less transpiration.

The total evapotranspiration during the crop growth period for IW/CPE of 0.9 was 386.3 mm.

Thus, in general, the evapotranspiration was initially low then increased up to the 87th day after sowing and then it was decreased up to the time of physiological maturity was.

Table 13b Cumulative ET as per IW/CPE ratio and physiological growth stagewise LAI for treatment with IW/CPE of 0.9

Treatment No.	IW/CPE ratio	Observation day	ET (mm)	PGS day	LAI
		19	53.9	20	0.276
		21	59.4	37	1.318
		46	139.7	53	2.004
T_2	0.9	69	249.3	70	1.529
		87	340.4	84	1.050
		104	386.3	104	0.297

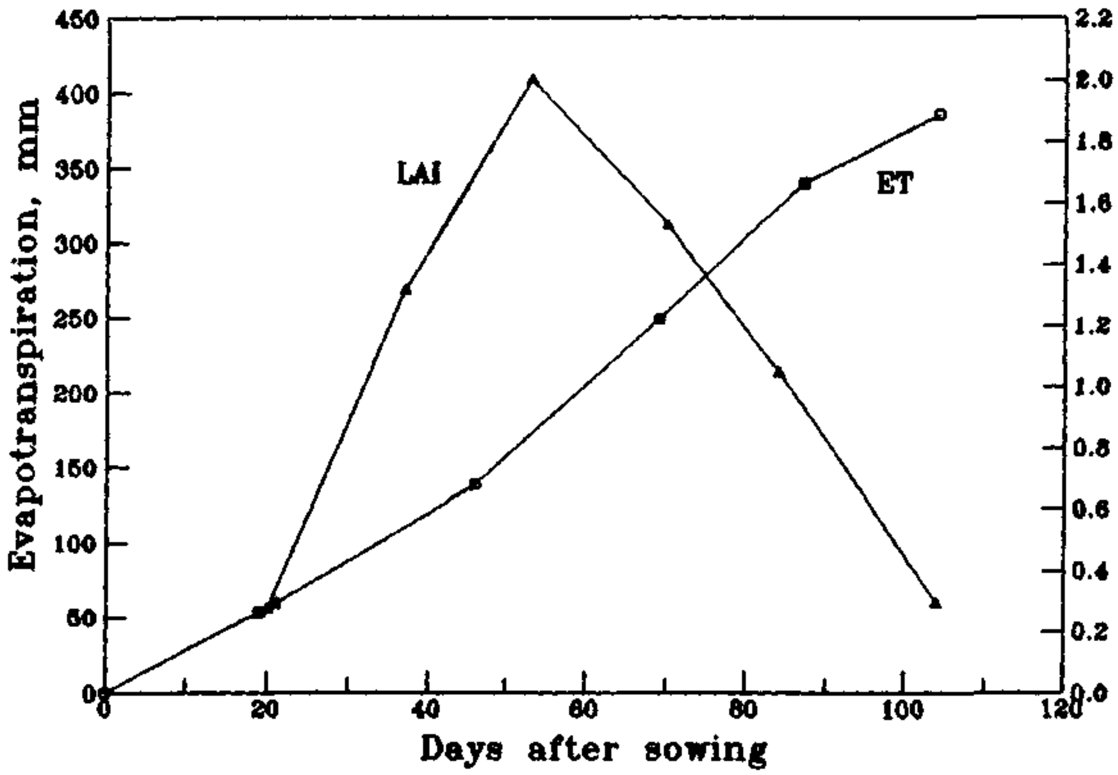

Fig. 10b Cumulative ET (mm) as per IW/CPE ratio and physiological growth stagewise LAI of the treatment with IW/CPE of 0.9

Treatment with IW/CPE of 0.8:

The data from the Table 13 (c) show that IW/CPE was given four irrigations during the crop growth period.

Fig. 10(c) shows cumulative evapotranspiration as per IW/CPE ratio and physiological growth stage wise leaf area index.

The evapotranspiration was initially low, i.e. 67 mm and average ET per day was 2.79 mm from sowing to the 24th day after sowing. It was because the crop was attained crown root initiation stage. The roots were under development due to which the absorption of water by the roots was less. The leaves were less in number and leaf area was small. Hence, the radiation intercepted was less and net energy available for loss of water through transpiration was less.

From the 25th to 52nd day after sowing, the evapotranspiration was 81.2 mm. The average daily ET was 2.90 mm. During this period the crop had attained the tillering stage and was approaching the jointing stage. The number of leaves and leaf area had increased. The ET was more as compared to initial period.

From the 53rd to 73rd day after sowing, the evapotranspiration was 102.1 mm. The average daily ET was 4.19 mm. The crop had completed jointing stage and attained flowering stage. At jointing stage the number of leaves and leaf area was highest due to which the intercepted energy was more and net energy available for transpiration increased. Also the absorption of water by the roots was more because they were well developed resulting in higher evapotranspiration.

From the 74th to 93rd day after sowing, the evapotranspiration was 93.5 mm. The average daily ET was 4.68 mm and was highest during the crop growth period. This was because the crop had completed the milk stage and third irrigation was given during this period.

Table 13c Cumulative ET as per IW/CPE ratio and physiological growth stagewise LAI for treatment with IW/CPE of 0.8

Treatment No.	IW/CPE ratio	Observation day	ET (mm)	PGS day	LAI
		19	53.9	20	0.274
		21	59.4	37	1.253
		24	67.0	53	1.849
T_3	0.8	52	148.2	70	1.404
		73	250.3	84	0.996
		93	343.8	104	0.292
		104	372.5	-	-

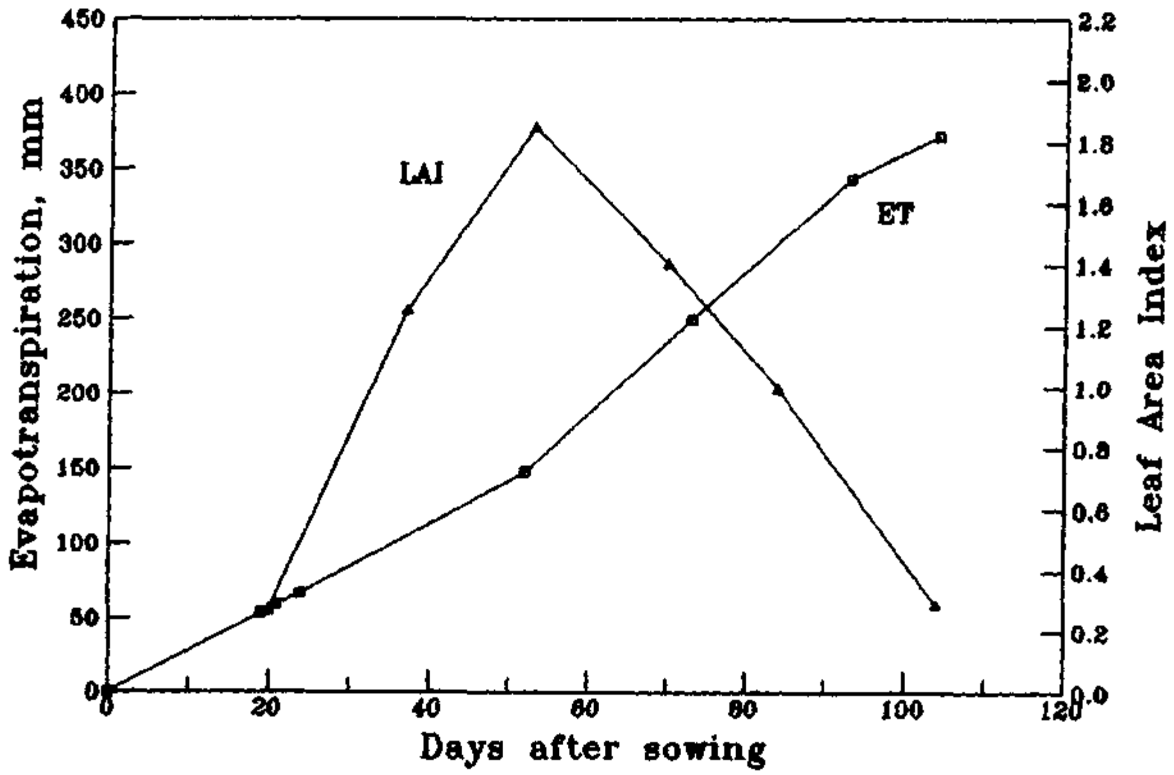

Fig. 10c Cumulative ET (mm) as per IW/CPE ratio and LAI as per physiological growth stages of the treatment wth IW/CPE of 0.8

From the 94th to 104th day after sowing, the evapotranspiration was 28.7 mm. The average daily ET was 3.19 mm. This was because at physiological maturity leaves had senescensed and effective leaf area had decreased resulting into less evapotranspiration.

The total evapotranspiration during the entire growth period for IW/CPE of 0.8 was 372.5 mm.

Thus, in general the ET was initially low,then went on increasing up to the 93rd day and afterwards it decreased up to physiological maturity stage.

Treatment with IW/CPE of 0.7:

The data from Table 13d shows that the treatment with IW/CPE of 0.7 was given 3 irrigations was given during the crop growth period.

Fig. 10(d) shows cumulative evapotranspiration as per IW/CPE ratio and physiological growth stage wise leaf area index.

The evapotranspiration was initially low, i.e. 69 mm and per day ET was 2.68 mm from sowing to the 26th day after sowing. This was because the crop had attained only crown root initiation stage. The roots were under development due to which absorption of water by roots was less. The leaves were less in number and leaf area was less. Because of this the radiation intercepted was less and net energy available for loss of water through transpiration was less.

From the 27th to 56th day after sowing, the evapotranspiration was 91.4 mm and per day ET was 3.05 mm. As compared to initial period it was higher. This was because the crop had attained the tillering and jointing stages. At jointing stage the number of leaves and leaf area had increased, due to which intercepted radiation was more and net energy available for transpiration increased.

Table 13d Cumulative ET as per IW/CPE ratio and physiological growth stagewise LAI for treatment with IW/CPE of 0.7

Treat-ment No.	IW/CPE ratio	Obser-vation day	ET (mm)	PGS day	LAI
		19	53.9	20	0.278
		21	59.4	36	1.213
		24	67.00	51	1.703
T_4	0.7	26	69.6	68	1.297
		56	161.0	82	0.908
		81	267.1	102	0.281
		102	316.3	-	-

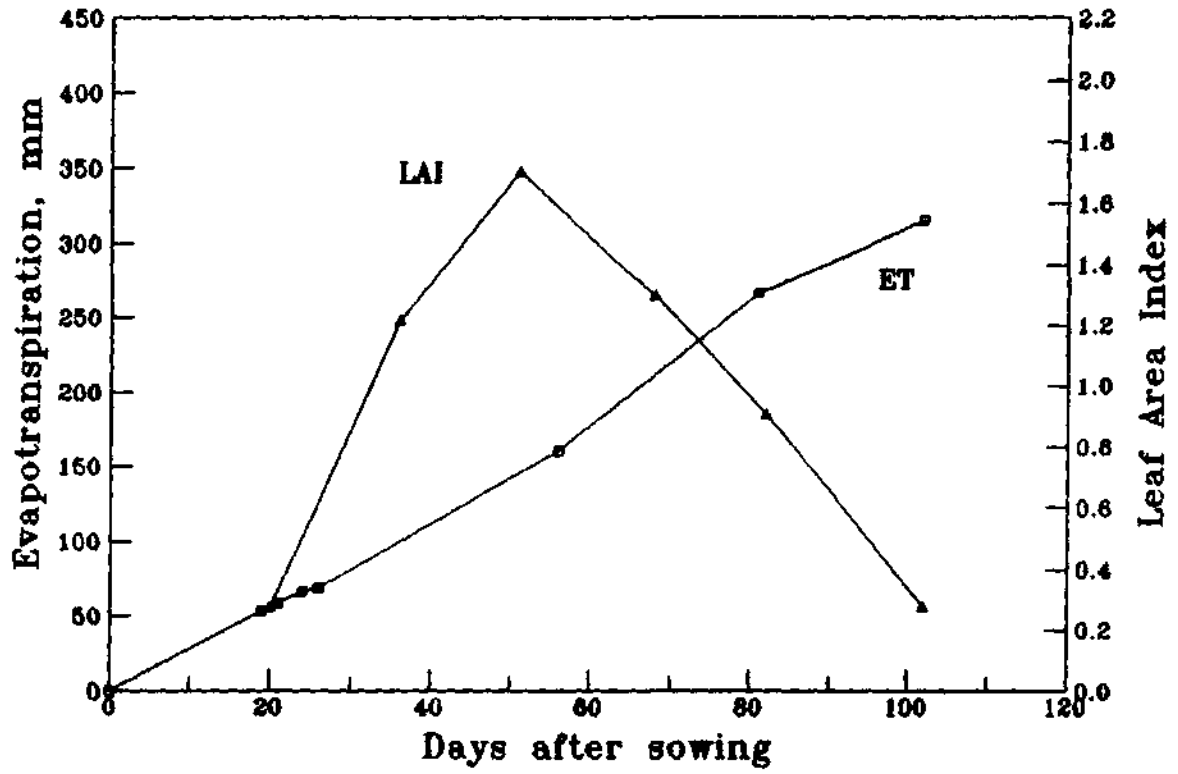

Fig. 10d Cumulative ET as per IW/CPE ratio and LAI as per physiological growth stages of treatment with IW/CPE of 0.7

From the 57^{th} to 87^{th} day after sowing, the evapotranspiration was 106.1 mm. Average daily ET was 4.24 mm which was highest. Because the crop had completed flowering stage. Also it was about to reach the milk stage and was given third irrigation during this period.

From the 82^{nd} to 102^{nd} day after sowing, the evapotranspiration was 49.1 mm. Average daily ET was 2.14 mm showing the decreasing trend. This was because the crop was approaching the physiological maturity. The senescence of leaves caused reduction in leaf area, which decreased the transpiration.

The total evapotranspiration during the crop growth period for the treatment with IW/CPE of 0.7 was 316.2 mm.

Thus, in general ET was initially low, then it went on increasing up to the 82^{nd} day after sowing and then decreased up to physiological maturity stage.

Treatment with IW/CPE of 0.6:

The data from Table 13c shows that the treatment with IW/CPE of 0.6 was given 3 irrigations during the crop growth period.

Fig. 10e shows cumulative evapotranspiration as per IW/CPE ratio and physiological growth stage wise leaf area index.

The evapotranspiration was initially low, i.e. 78.2 mm and per day ET was 2.52 mm from sowing to the 31^{st} day after sowing. This was because the crop had attained only crown root initiation stage. The roots were under development due to which absorption of water by roots was less. The leaves were less in number and leaf area was less. Because of this the radiation intercepted was less and net energy available for loss of water through transpiration was less.

From the 32^{nd} to 66^{th} day after sowing, the evapotranspiration was 104.4 mm and per day ET was 2.98 mm. As compared to initial period it was higher. This was because the crop had attained the tillering and jointing stages. At jointing stage the number of leaves and leaf area had increased, due to which

Table 13e Cumulative ET as per IW/CPE ratio and physiological growth stagewise LAI for treatment with IW/CPE of 0.6

Treat-ment No.	IW/CPE ratio	Obser-vation day	ET (mm)	PGS day	LAI
		19	53.9	20	0.274
		21	59.4	36	1.142
		24	67.00	51	1.595
T_5	0.6	26	69.6	68	1.210
		31	78.2	82	0.836
		66	182.6	102	0.268
		93	269.0	-	-
		102	296.2	-	-

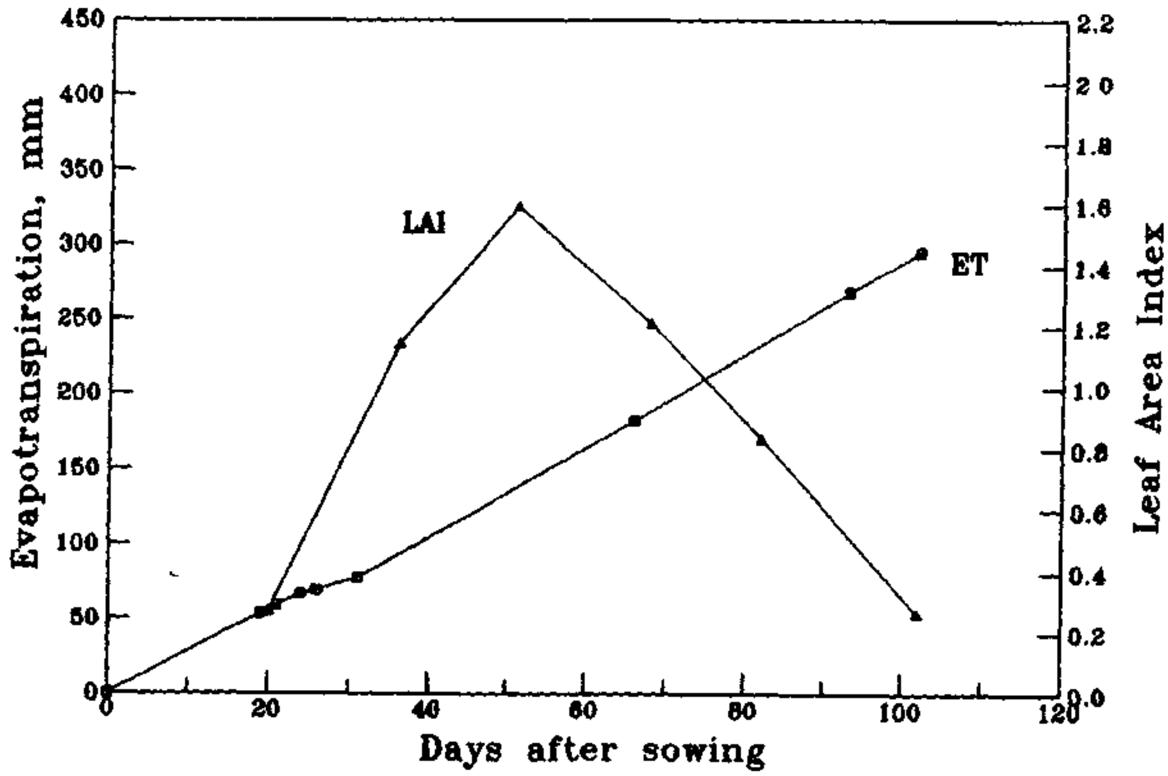

Fig. 10(e) Cumulative ET (mm) as per IW/CPE ratio and LAI as per crop growth stges of the treatment with IW/CPE of 0.6

intercepted radiation was more and net energy available for transpiration increased.

From the 67th to 93th day after sowing, the evapotranspiration was 86.2 mm. Average daily ET was 3.2 mm which was highest. This was because the crop had attained the flowering and milk stages and was given third irrigation during this period.

From the 94nd to 102nd day, the evapotranspiration was 27.2 mm. Average daily ET was 3.02 mm showing the decreasing trend. This was because the crop was approaching the physiological maturity. The senescence of leaves caused reduction in leaf area, which decreased the transpiration.

The total evapotranspiration during the crop growth period for the treatment with IW/CPE of 0.6 was 296.2 mm.

Thus, in general ET was initially low, then it went on increasing up to the 82nd day after sowing and then decreased up to physiological maturity.

Treatment with IW/CPE of 0.5:

The data from Table 13f shows that treatment with IW/CPE with 0.5 was given two irrigations during the crop growth period.

Fig. 10(f) shows cumulative evapotranspiration as per IW/CPE ratio and physiological growth stagewise leaf area index.

The evapotranspiration was initially low i.e. 87.40 mm and per day ET was 2.24 mm up to the 39th day after sowing, which was lowest during the crop growth period. This is due to the fact that the crop had attained crown root initiation and tillering stage and crop was not given a single irrigation.

From the 40th to 78th days after sowing, the evapotranspiration was 102.6 mm. The average ET was 2.63 mm which was highest during the crop growth period. This was because the crop had completed jointing and flowering stage.

Table 13f Cumulative ET as per IW/CPE ratio and physiological growth stagewise LAI for treatment with IW/CPE of 0.5

Treat-ment No.	IW/CPE ratio	Obser-vation day	ET (mm)	PGS day	LAI
		19	53.9	20	0.275
		21	59.4	35	1.085
		24	67.00	49	1.405
		26	69.6	65	1.120
T_6	0.5	31	78.2	79	0.729
		39	87.4	99	0.256
		78	190.0	-	-
		99	238.9	-	-

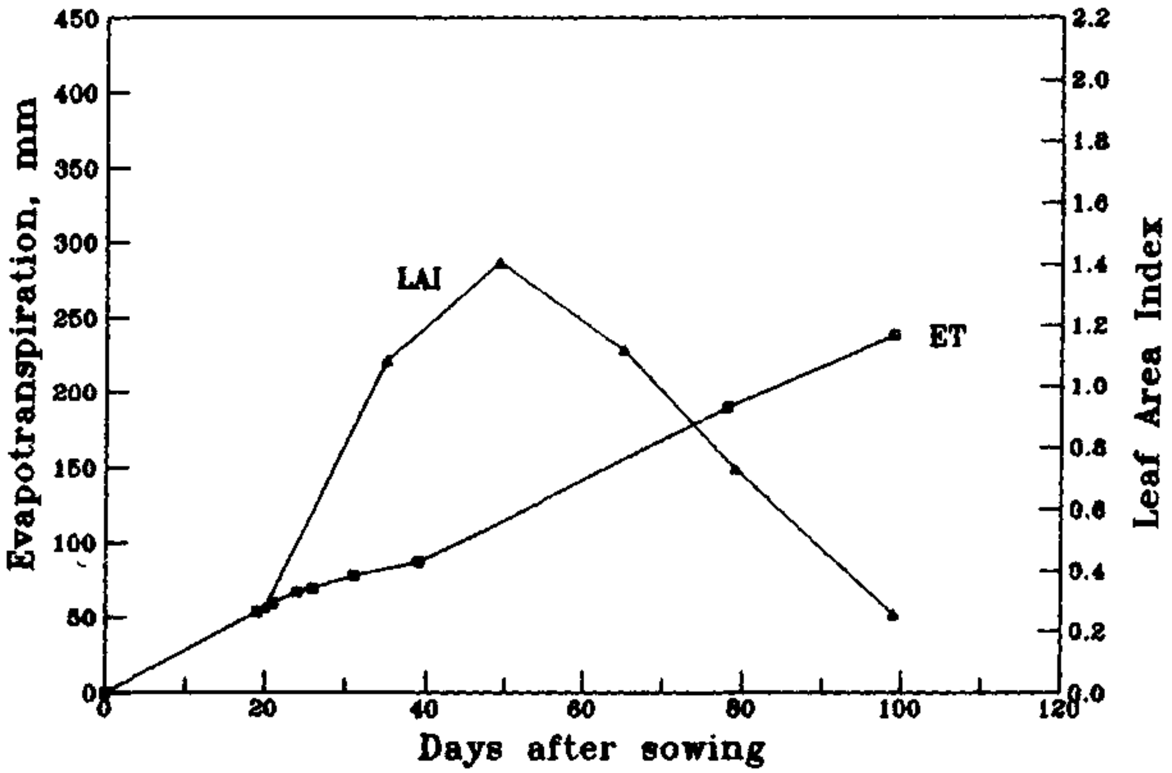

Fig. 10(f) Cumulative ET (mm) as per IW/CPE ratio and LAI as per crop growth stages of the treatment with IW/CPE of 0.5

At jointing stage the number of leaves and leaf area was maximum due to which radiation intercepted was more and net energy available for transpiration was more. Also the absorption of water by the roots was more as they were well developed.

From 79th to 99th day after sowing the evapotranspiration was 48.9 mm. The daily average ET was 2.45 mm. The ET showed the decreasing because the senescence of leaves caused reduced leaf area, reducing transpiration.

The total evapotranspiration during the entire crop growth period was 238.9 mm.

Thus, in general, the evapotranspiration was initially low, then it went on increasing up to 78th day after sowing and again it decreased at the time of physiological maturity.

Treatment with IW/CPE of 0.4:

The data from Table 13(g) shows that treatment with IW/CPE with 0.4 was given two irrigations during the crop growth period.

Fig. 10(g) shows cumulative evapotranspiration as per IW/CPE ratio and physiological growth stagewise leaf area index.

The evapotranspiration was initially low i.e. 104.9 mm and per day ET was 2.02 mm from sowing to the 52nd day after sowing, which was lowest during the crop growth period. This is due to the fact that the crop had attained crown root initiation, tillering and jointing stages and crop was not given a single irrigation.

From the 53rd to 94th days after sowing, the evapotranspiration was 107.2 mm. The average ET was 2.50 mm which was highest during the crop growth period. The crop had attained flowering and milk stage and was given one irrigation during this period.

Table 13g Cumulative ET as per IW/CPE ratio and physiological growth stagewise LAI for treatment with IW/CPE of 0.4

Treatment No.	IW/CPE ratio	Observation day	ET (mm)	PGS day	LAI
		19	53.9	20	0.272
		21	59.4	35	1.608
		24	67.00	49	1.276
		26	69.6	65	1.063
T_6	0.5	31	78.2	79	0.623
		39	87.4	99	0.249
		52	104.9	-	-
		94	212.1	-	-
		99	231.8	-	-

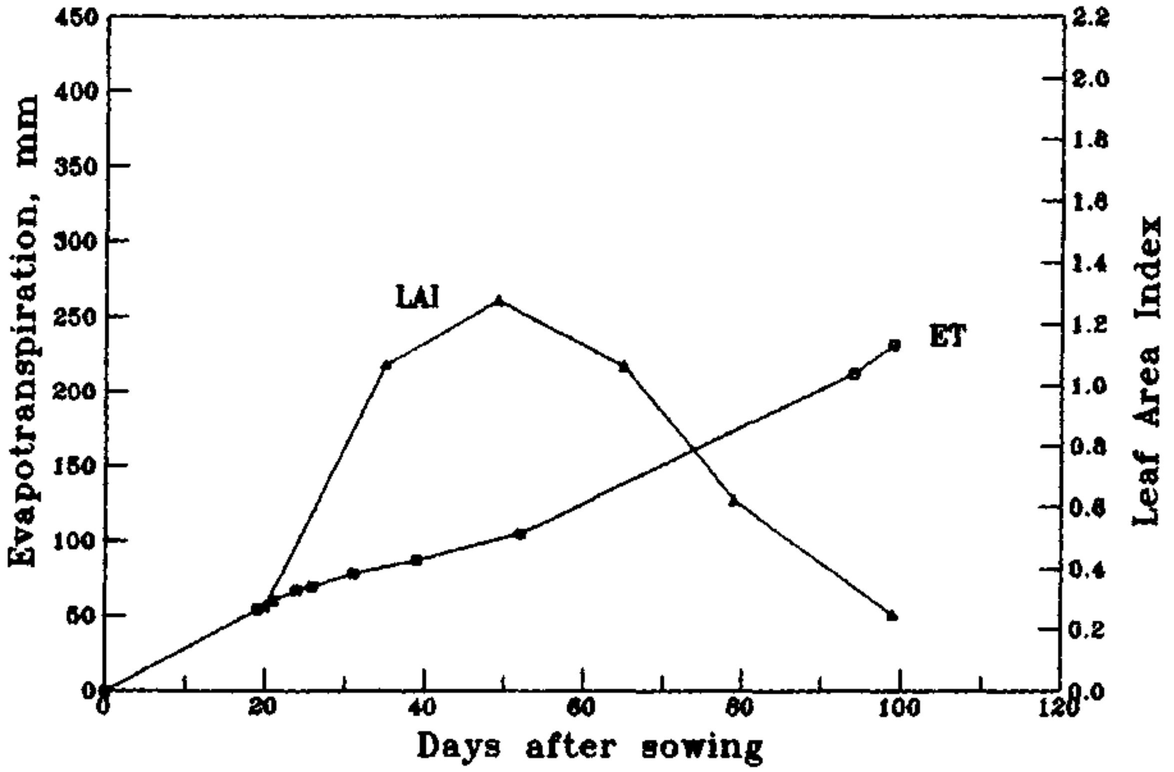

Fig. 10(g) Cumulative ET (mm) as per IW/CPE ratio and LAI as per physiological growth stages of treatment with IW/CPE of 0.4

The leaf area was maximum due to which the energy intercepted was more and the net energy available for transpiration had increased. The crop had received one irrigation increasing soil moisture status. Also the absorption of water by the roots was more which resulted in maximum ET.

From the 95th to 199th day after sowing the evapotranspiration was 19.7 mm. The daily average ET was 4.93 mm. The per day ET was highest during this period because the crop was given second irrigation on the 94th day which increased the soil moisture status and the crop matured on the 99th day. During this period the temperature was more and windy conditions occur due to which per day ET was more.

The total evapotranspiration during the entire crop growth period was 231.8 mm.

Thus, in general, the evapotranspiration increased with increase in number of irrigations as per IW/CPE ratio and decreases with decrease in number of irrigations as per IW/CPE ratio. Similar type of results were reported by Gowda (1972), Prihar et al. (1973), Prabhakar et al. (1981), Reddy (1985) and Malvia (1987).

4.6 Daily Potential evapotranspiration (PET) and Vapour pressure deficit (VPD) during crop growth period:

The data regarding daily PET and VPD are presented in Table 14 and Fig. 11. The data shows that the daily PET value ranged between 2.31 mm and 5.62 mm ; and the daily VPD value ranged between 6.22mb and 15.10 mb during crop growth period.

Table 14. Daily PET (mm) and VPD (mb) during crop growth period

Week No.	Date	PET (mm)	VPD (mb)
46	12-11-89	3.39	9.87
	13-11-89	3.52	8.68
	14-11-89	3.64	8.67
	15-11-89	3.55	9.39
	16-11-89	3.37	9.82
	17-11-89	3.41	12.02
	18-11-89	3.56	10.82
47	19-11-89	3.24	9.40
	20-11-89	3.14	9.48
	21-11-89	3.04	8.85
	22-11-89	3.42	9.87
	23-11-89	3.15	11.24
	24-11-89	3.00	11.20
	25-11-89	3.16	8.62
48	26-11-89	3.12	9.70
	27-11-89	3.14	8.49
	28-11-89	2.91	8.87
	29-11-89	2.92	8.55
	30-11-89	3.17	9.27
	01-12-89	3.08	8.58
	02-12-89	3.25	8.44
49	03-12-89	3.07	8.40
	04-12-89	2.86	8.14

Table 14 (Continued ...)

(Contınued ...)

Week No.	Date	PET (mm)	VPD (mb)
	05-12-89	2.50	8.11
	06-12-89	2.71	8.34
	07-12-89	2.95	9.68
	08-12-89	2.50	8.02
	09-12-89	2.57	7.28
50	10-12-89	2.36	6.68
	11-12-89	2.60	7.29
	12-12-89	2.32	7.15
	13-12-89	2.54	6.90
	14-12-89	2.76	6.60
	15-12-89	2.80	6.78
	16-12-89	2.66	7.55
51	17-12-89	2.59	6.63
	18-12-89	2.54	6.22
	19-12-89	2.82	7.08
	20-12-89	2.37	6.49
	21-12-89	2.33	7.64
	22-12-89	2.66	8.83
	23-12-89	2.86	9.64
52	24-12-89	2.49	6.76
	25-12-89	2.53	8.27
	26-12-89	2.66	8.02
	27-12-89	2.51	7.20

Table 14 (Contınued ...)

(Continued ...)

Week No.	Date	PET (mm)	VPD (mb)
	28-12-89	2.46	7.57
	29-12-89	2.28	7.42
	30-12-89	2.73	6.53
	31-12-89	2.31	7.12
1	01-01-90	2.85	7.67
	02-01-90	2.94	9.77
	03-01-90	2.78	9.60
	04-01-90	3.14	8.69
	05-01-90	2.88	7.91
	06-01-90	2.94	8.54
	07-01-90	2.91	8.05
2	08-01-90	2.73	8.60
	09-01-90	3.09	8.02
	10-01-90	3.07	9.12
	11-01-90	2.80	9.98
	12-01-90	2.70	8.99
	13-01-90	2.77	9.94
	14-01-90	2.53	11.40
3	15-01-90	2.60	10.25
	16-01-90	2.61	9.49
	17-01-90	2.53	9.41

Table 14 (Continued ...)

(Continued ...)

Week No.	Date	PET (mm)	VPD (mb)
	18-01-90	2.68	9.94
	19-01-90	2.67	10.23
	20-01-90	2.74	11.40
	21-01-90	2.73	10.51
4	22-01-90	2.71	8.51
	23-01-90	2.84	9.84
	24-01-90	2.84	9.45
	25-01-90	2.70	10.44
	26-01-90	2.81	11.28
	27-01-90	2.75	11.62
	28-01-90	2.63	12.57
5	29-01-90	2.71	10.90
	30-01-90	2.93	12.09
	31-01-90	2.79	12.55
	01-02-90	3.42	12.35
	02-02-90	3.46	10.06
	03-02-90	3.40	11.28
	04-02-90	3.36	12.32
6	05-02-90	3.48	12.43
	06-02-90	3.35	10.83
	07-02-90	3.73	10.77
	08-02-90	3.79	10.17

Table 14 (Continued ...)

(Continued ...)

Week No.	Date	PET (mm)	VPD (mb)
	09-02-90	3.50	10.30
	10-02-90	3.36	10.26
	11-02-90	3.73	10.82
7	12-02-90	4.05	12.16
	13-02-90	3.58	10.72
	14-02-90	3.84	10.48
	15-02-90	4.03	12.37
	16-02-90	3.88	9.36
	17-02-90	3.48	10.01
	18-02-90	4.40	9.10
8	19-02-90	3.64	8.80
	20-02-90	3.42	10.58
	21-02-90	3.52	9.18
	22-02-90	3.49	10.71
	23-02-90	3.49	10.22
	24-02-90	3.38	11.34
	25-02-90	3.60	10.87
9	26-02-90	3.52	10.01
	27-02-90	3.74	14.04
	28-02-90	4.74	10.22
	01-03-90	5.61	11.08
	02-03-90	4.63	10.57

Table 14 (Continued ...)

(Continued ...)

Week No.	Date	PET (mm)	VPD (mb)
	03-03-90	4.34	10.40
	04-03-90	4.31	7.78
10	05-03-90	4.58	9.00
	06-03-90	5.62	11.37
	07-03- 90	4.61	12.50
	08-03-90	4.77	10.75
	09-03-90	4.77	14.30
	10-03-90	4.37	15.10
	11-03-90	5.37	12.23

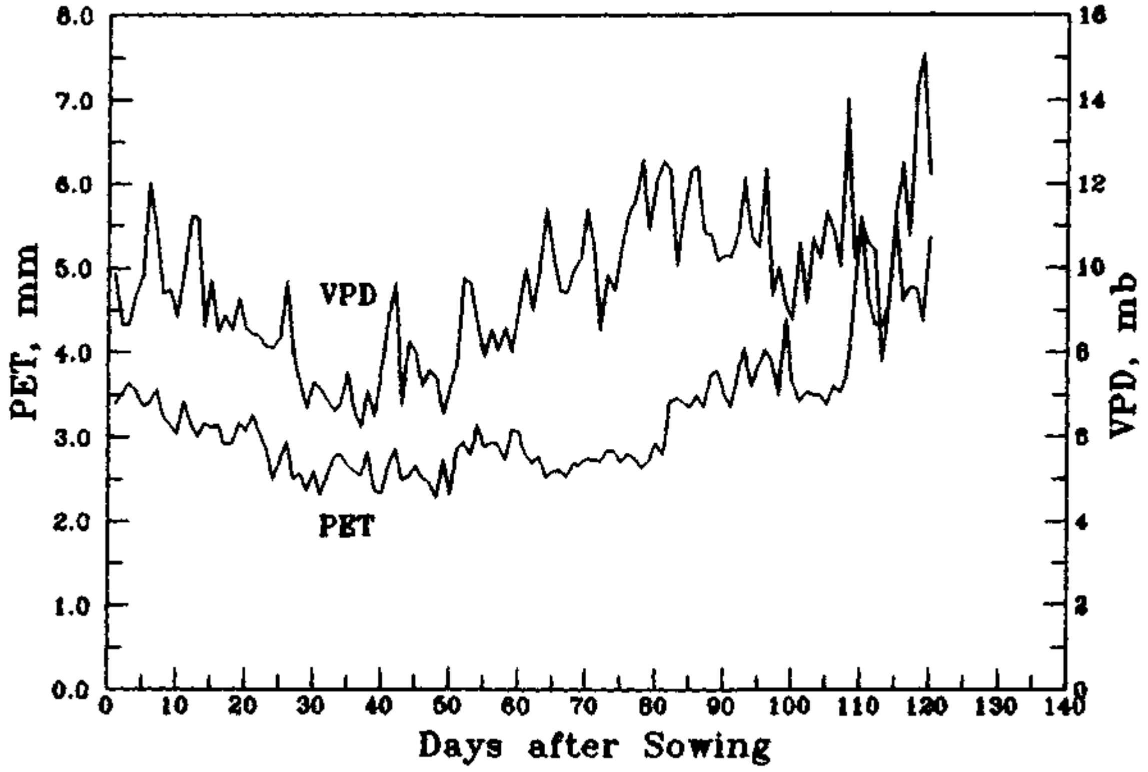

Fig. 11 Daily PET (mm) and VPD (mb) during crop growth period

4.7 CUMULATIVE ET (mm), PET (mm) AND VPD (mb) AS PER IW/CPE RATIO FOR IRRIGATION TREATMENTS:

The data regarding ET, PET and VPD as per IW/CPE are presented in Table 15 and graphically shown in Fig. 12 (a) to 12 (g).

The treatment with IW/CPE of 1.0 recieved five irrigations while IW/CPE of 0.9 and 0.8 recieved four irrigations each Figs. 12 (a,b,c) show that initially PET was more than ET for all the treatments because the crop was at the edge of Crown root initiation stage with less number of leaves and less leaf area, resulting in less transpiration. Up to the 33rd and 35th days in the case of IW/CPE of 1.0 and 0.9 respectively and up to the 49th day in case the of IW/CPE of 0.8 the ET was more than PET. This was because of the fact that irrigations were given to these treatments and due to the increase in the number of leaves and leaf area, resulting in more transpiration.

The treatments with IW/CPE of 0.7 and 0.6 were given three irrigations. Figs. 12 (d,e) show that initially IW/CPE of 0.7 showed low rating than PET. On the 56th day, ET and PET were almost on par with each ther. Afterwards, the ET was more than PET up to the physiological maturity stage. This was because, during this period the crop was in actively growing stage, resulting in increased ET. The treatment with IW/CPE of 0.6 showed that ET and PET were almost on par with each other. Figs. 12 (f) and 12 (g) shows that for the treatments with IW/CPE 0.5 and 0.4 the ET was always less than PET as both the treatments recieved only two irrigations during crop growth period.

Fig. 12(a) to 12 (g) shows that with increase VPD, the ET and PET was also increased. This was because the difference between dry bulb and wet bulb temperature was more. Due to higher air temperature, the loss of water from soil and plant was more which resulted in more ET.

Table 15 Cumulative ET (mm), PET (mm) and VPD (mb) as per IW/CPE ratio

Treat-ment	IW/ CPE ratio	char-acter	Days after sowing					
			19	39	61	78	94	108
		ET	53.90	117.60	220.20	310.40	388 30	432 60
T_1	1.0	PET	60.01	111.94	172 15	219 24	277 26	332.78
		VPD	179.16	328.11	516 77	699.35	874.16	1021.28

Treat-ment	IW/ CPE ratio	char-acter	Days after sowing					
			19	21	46	69	87	104
		ET	53.90	59.40	139.70	249.30	340.40	386.30
T_2	0.9	PET	60.01	65.22	129.42	193.66	250.67	313.46
		VPD	179.16	195.61	380.24	596.10	798 27	97

Treat-ment	IW/ CPE ratio	char-acter	Days after sowing						
			19	21	24	52	73	93	104
		ET	53.90	59 40	67 00	148 20	250 30	343.80	372.50
T_3	0 8	PET	60.01	65.22	73 24	146 95	204 76	273 78	313 46
		VPD	179.16	195 61	220 59	432.42	638.59	864.15	979.01

Treat-ment	IW/ CPE ratio	char-acter	Days after sowing						
			19	21	24	26	56	81	102
		ET	53 90	59.40	67 00	69.60	161 00	267.10	316.20
T_4	0 7	PET	60.01	65 22	73 24	78 20	158 75	229.46	306.20
		VPD	179.16	195 61	220.59	234.56	466.21	733.51	954 96

Treat-ment	IW/ CPE ratio	char-acter	Days after sowing							
			19	21	24	26	31	66	93	102
		ET	53 90	59.40	67.00	69.60	78 20	182.60	269 00	296 20
T_5	0.6	PET	60.01	65.22	73 24	78 20	91 28	185.38	273 78	306.20
		VPD	179.16	195.61	220 59	234 56	268 82	567 24	864.15	954 96

Table 15 (Continued .)

(Continued ..)

Treat-ment	IW/ CPE ratio	char-acter	Days after sowing								
			19	21	24	26	31	39	78	99	
		ET	53.90	59 40	67 00	69.60	78 20	87.40	190 00	238 90	
T_6	0.5	PET	60 01	65.22	73 24	78.20	91.28	111 94	219.14	295 73	
		VPD	179.16	195.61	220.59	234.56	268.82	328.11	699 35	922.53	
			Days after sowing								
			19	21	24	26	31	39	52	94	99
		ET	53.90	59.40	67 00	69 60	78.20	87.40	104.90	212.10	231.80
T_7	0.4	PET	60 01	65.22	73.24	78.20	91.28	11 94	146 95	277 26	295.73
		VPD	179.16	195.61	220 59	234.56	268.82	328.11	432.42	874.16	922.53

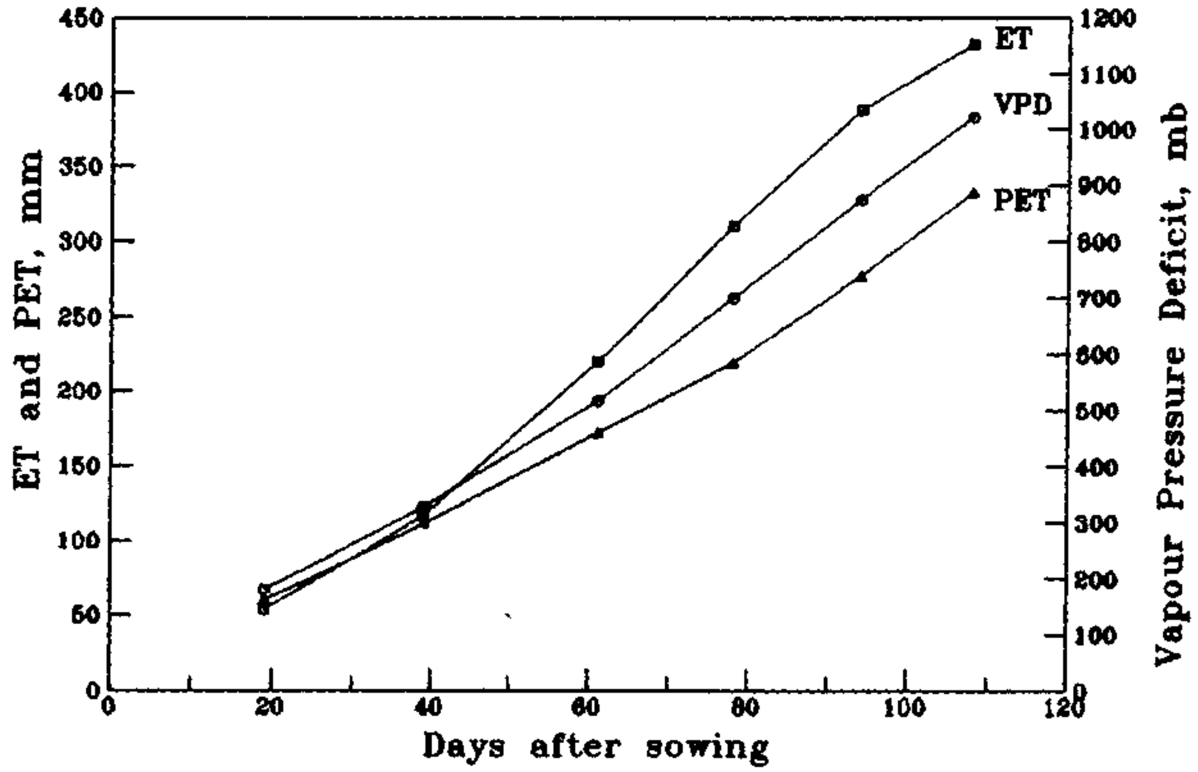

Fig. 12a Cumulative ET (mm), PET (mm) and VPD (mb) as per IW/CPE ratio of treatment with IW/CPE of 1.0

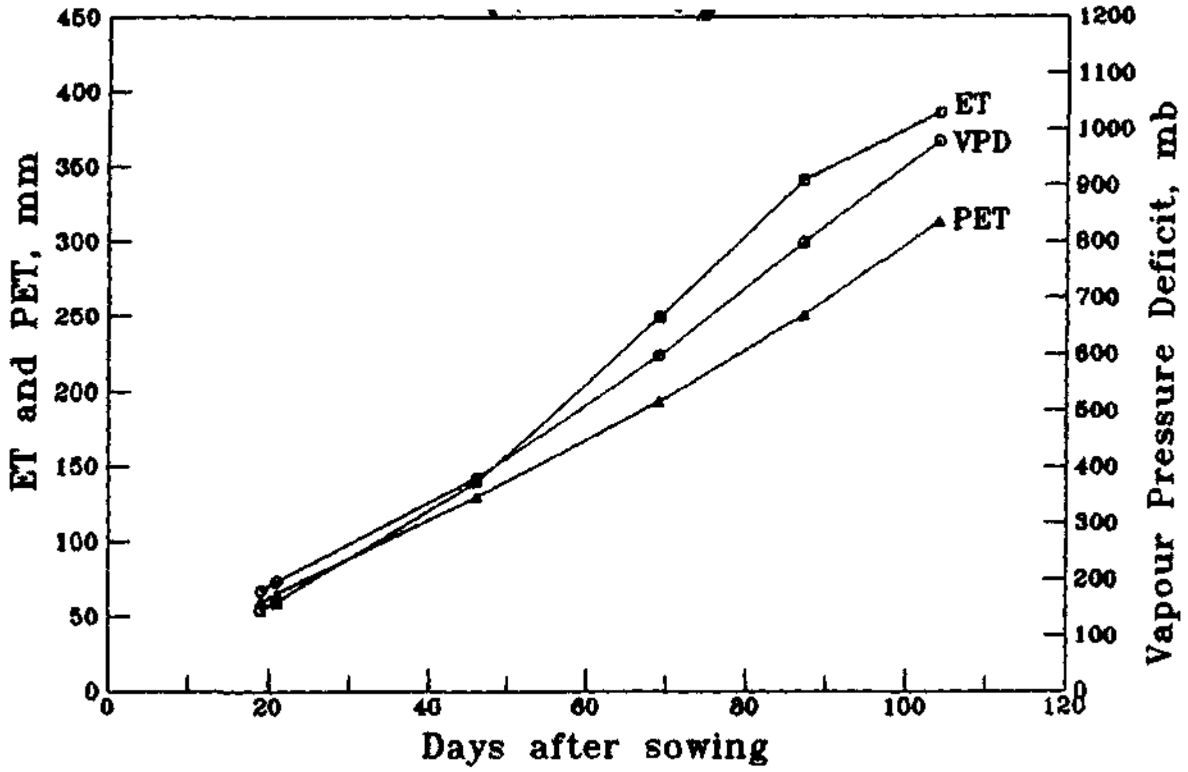

Fig. 12b Cumulative ET (mm), PET (mm) and VPD (mb) as per IW/CPE ratio of treatment with IW/CPE of 0.9

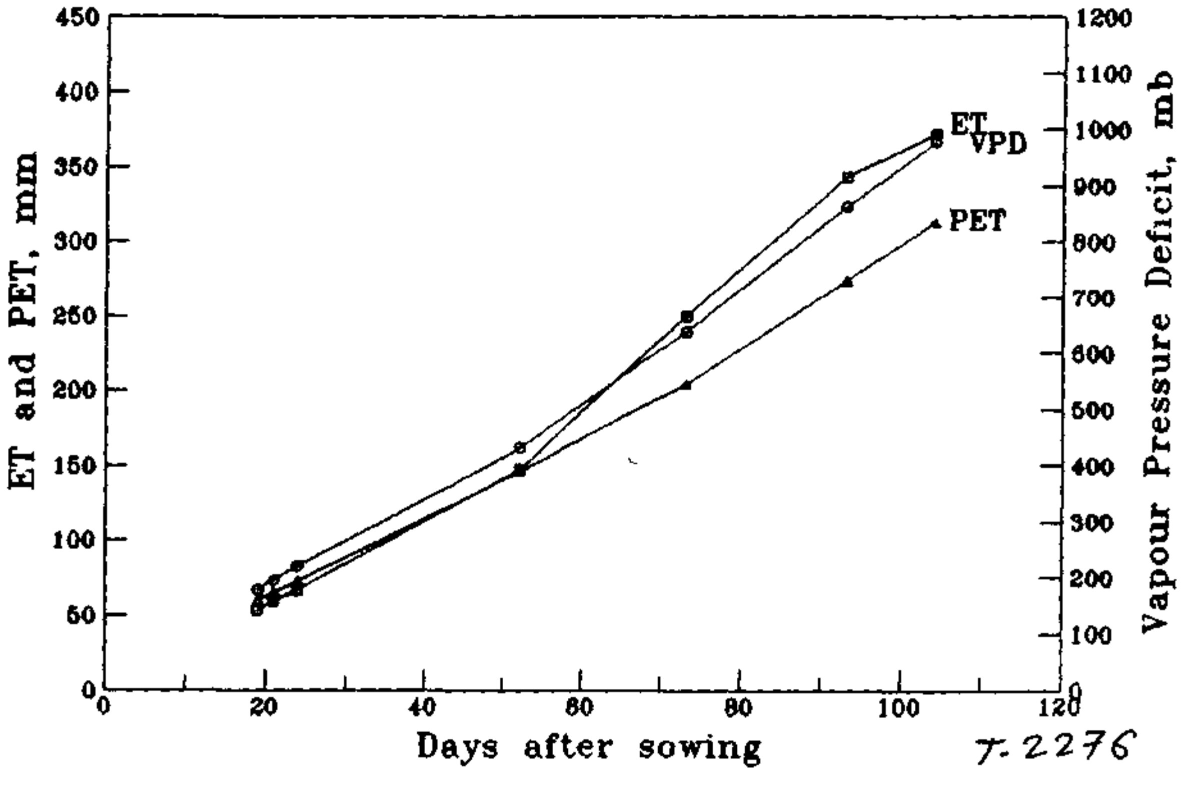

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Fig. 12c Cumulative ET (mm), PET (mm) and VPD (mb) as per IW/CPE ratio of treatment with IW/CPE of 0.8

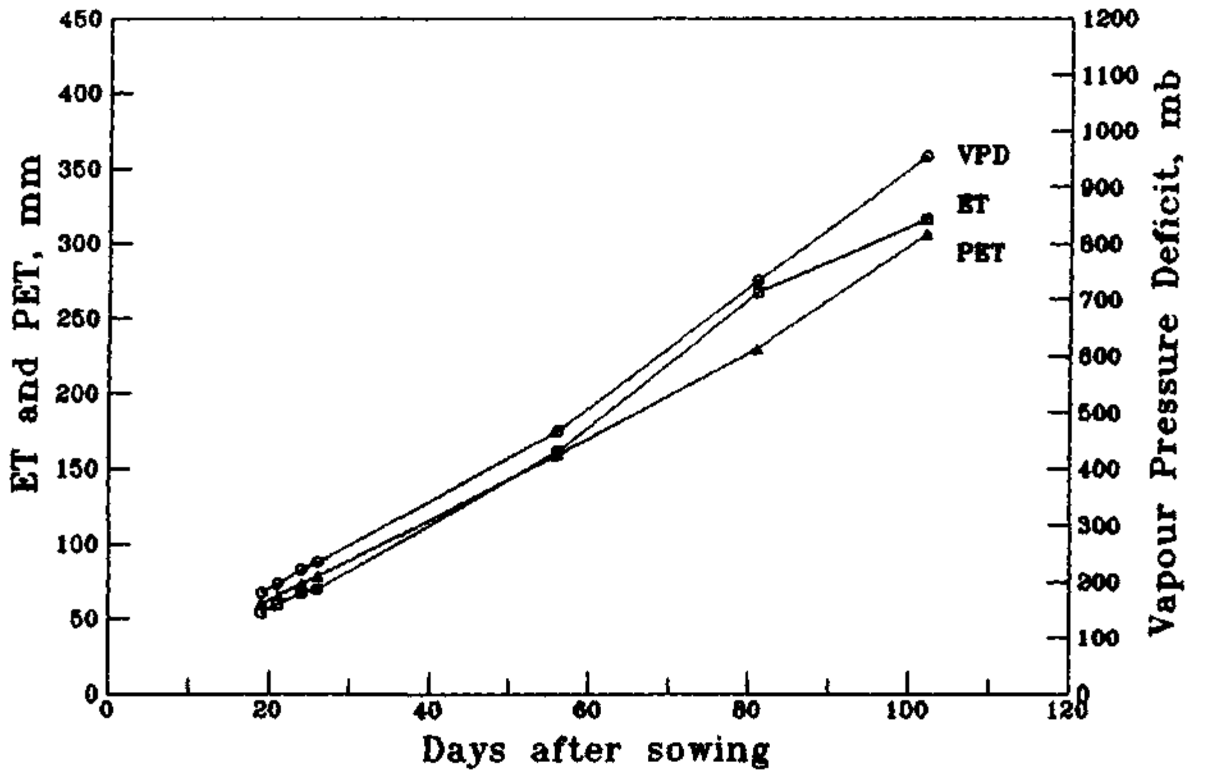

Fig. 12d Cumulative ET (mm), PET (mm) and VPD (mb) as per IW/CPE ratio of treatment with IW/CPE of 0.7

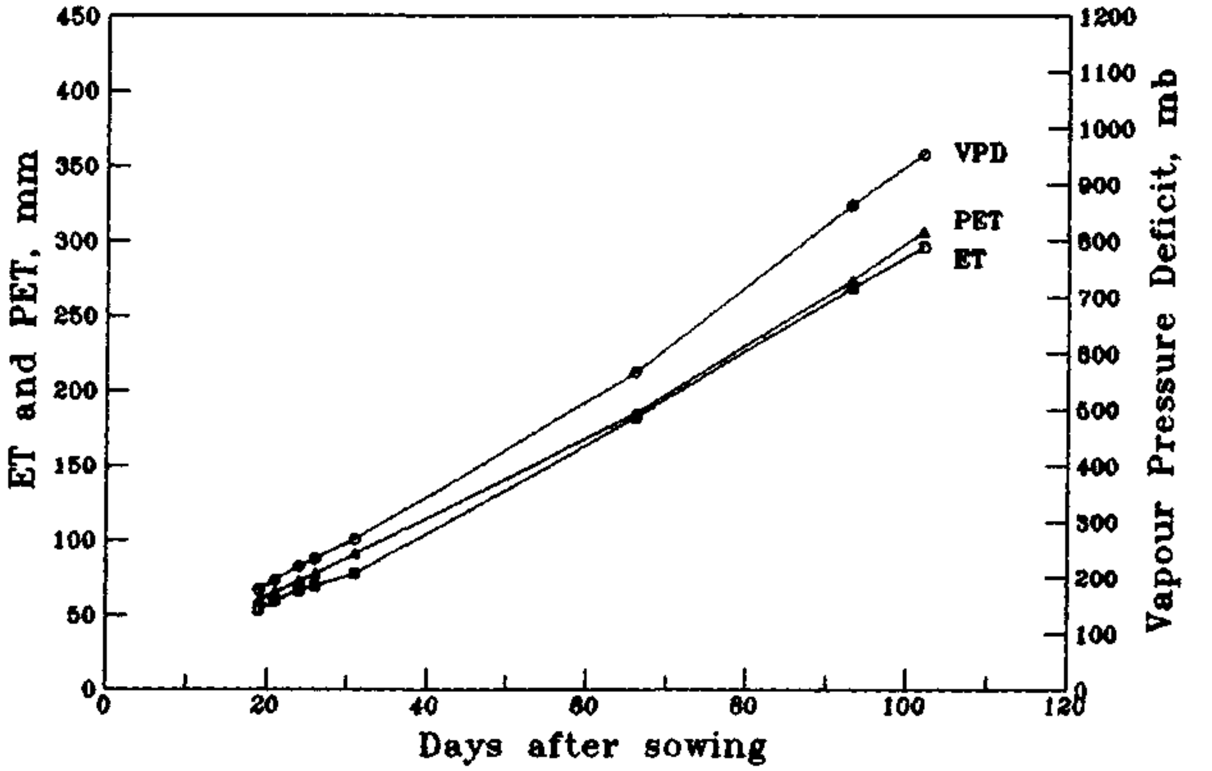

Fig. 12e Cumulative ET (mm), PET (mm) and VPD (mb) as per IW/CPE ratio of treatment with IW/CPE of 0.6

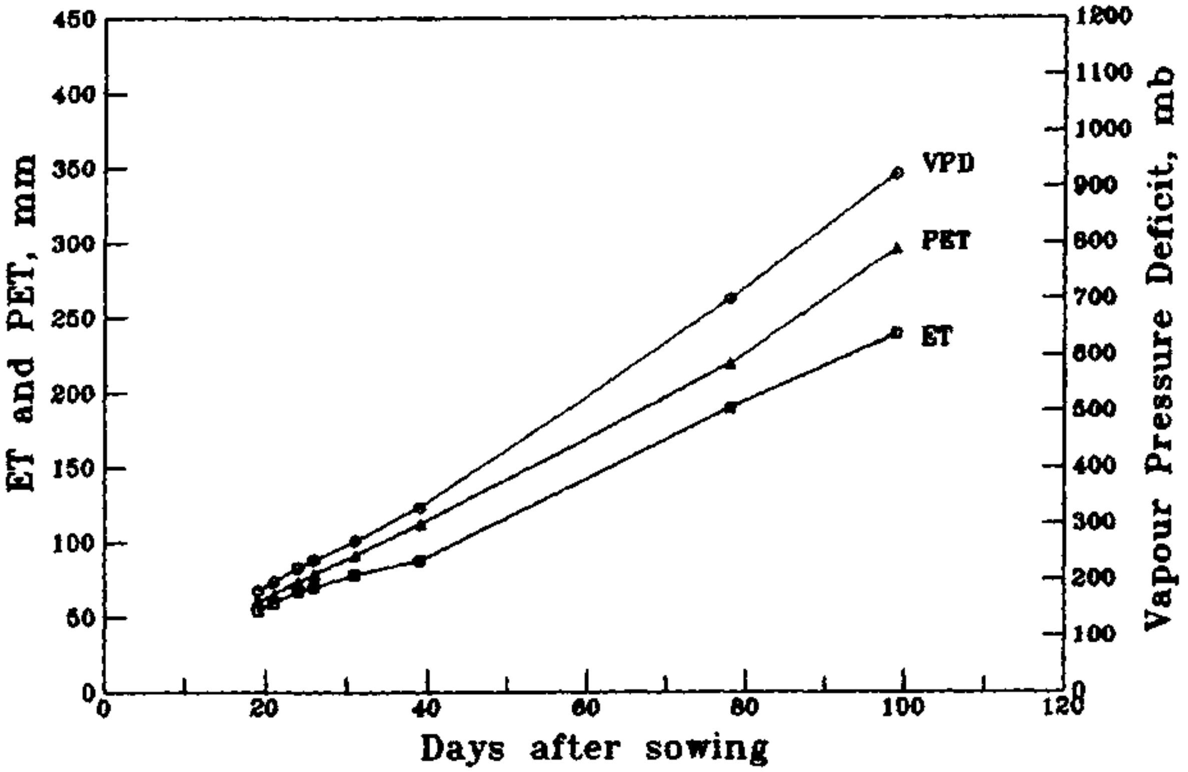

Fig. 12f Cumulative ET (mm), PET (mm) and VPD (mb) as per IW/CPE ratio of treatment with IW/CPE of 0.5

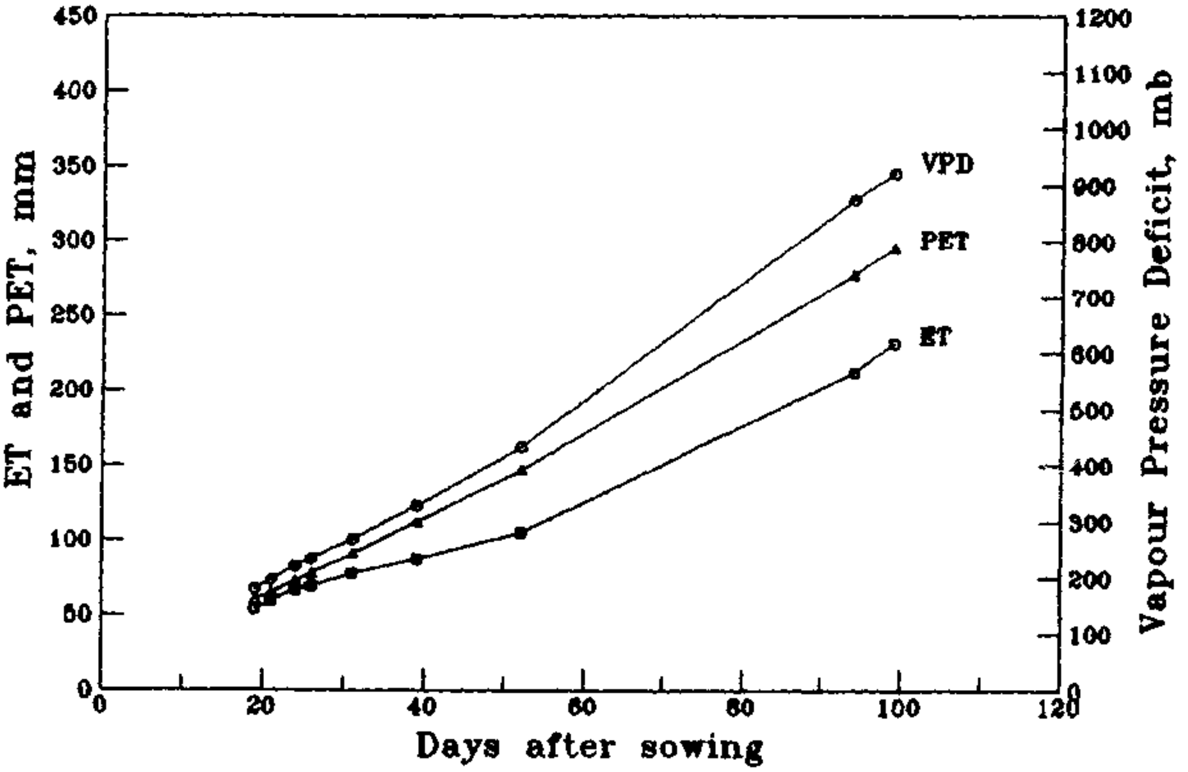

Fig. 12g Cumulative ET (mm), PET (mm) and VPD (mb) as per IW/CPE ratio of treatment with IW/CPE of 0.4

The relationship between ET, PET and VPD is described in Fig 12(a) to 12 (g). The PET was less than ET in the case of the treatments with IW/CPE of 1.0, 0.9 and 0.8. The PET was more than ET in the case of the treatment with IW/CPE of 0.5 and 0.4. In the case of IW/CPE of 0.7, PET was nearer to ET and in the case of IW/CPE of 0.6, ET was slightly less than PET. This indicates that the treatment with IW/CPE of 0.7 was the best. This was because the irrigations were applied only to fulfill the demand of atmosphere governed by vapour pressure deficit.

4.8 ET(mm), PET (mm), VPD (mb) AND LAI AS PER DIFFERENT PHYSIOLOGICAL GROWTH STAGES:

The data regarding ET, PET, VPD and LAI at the different physiological growth stages are presented in Table 16 and graphically shown in Figs. 13 (a) to 13 (b).

Crown root initiation stage (CRI):

At CRI stage, the ET (58mm) and LAI (0.288) where the highest in the treatment with IW/CPE of 1.0. The PET (62.51 mm) and VPD (187.2 mb) were the same for all the treatments.

This was because the CRI stage occurred on the 20th day after sowing for all the treatments. Up to this stage, only IW/CPE of 1.0 received one irrigation due to which IW/CPE of 1.0 had more number of leaves and leaf area index. Due to this, the transpiration losses in this treatment were more and hence the ET was slightly more than that in the other treatments.

Table 16 ET (mm), PET (mm), VPD(mm) and LAI as per different physiological growth stages for irrigation treatments

Treat-ment No.	IW/CPE ratio	Chara-cter	Physiological Growth Stages: CRI	Tillering	Jointing	Flower-	Milk-	Maturity
T_1	1.0	ET	58.00	54.00	68.00	92.00	76.00	84.60
		PET	62.51	44 08	43.270	49.270	48.110	85.470
		VPD	187.27	124 44	128.76	175.52	172.02	233.27
		LAI	0.288	1.379	2.099	1.619	1.107	0.307
T_2	0.9	ET	56.00	53.00	64.00	83.00	68.00	62.30
		PET	62.51	44.08	43.270	46.90	43.52	73.44
		VPD	187.27	124.44	128.76	165.08	161.99	211.47
		LAI	0.276	1.312	2 004	1.529	1.050	0.297
T_3	0.8	ET	56.00	50.00	52.00	77.00	66.00	71.50
		PET	62.51	44.08	43 27	46.90	43.52	73 44
		VPD	187.27	124.44	128.76	165.08	161.99	211.47
		LAI	0.274	1 253	1.849	1.404	0.996	0 292
T_4	0.7	ET	56.00	44 00	47.00	65.00	56.00	48.20
		PET	62.51	41 42	40.08	46.81	42.12	73 26
		VPD	187.27	115.61	121.00	162.38	159 68	209.02
		LAI	0.278	1.213	1.703	1.297	0.908	0 281
T_5	0.6	ET	56 00	37 00	45.00	52.00	45.00	61.20
		PET	62.51	41.42	40.08	46.81	42.12	73.26
		VPD	187.27	115.61	121.00	162 38	159 68	209.02
		LAI	0.274	1 142	1 595	1.210	0.836	0.268
T_6	0.5	ET	56 00	28 00	30.00	42.00	36.00	46.90
		PET	62.51	36.720	38.760	40.65	40.06	73.030
		VPD	187.27	107.94	112.04	148.56	153.27	213 12
		LAI	0.275	1.085	1.405	1.120	0 729	0.256

(Table 16 Continued ..)

(Continued...)

Treat-ment No.	IW/CPE ratio	Chara-cter	Physiological Growth Stages CRI	Tillering	Jointing	Flower-	Milk-	Maturity
		ET	56.00	28.00	16.00	37 00	34.00	60.80
		PET	62.51	36.720	38.760	40.650	40.060	73.030
T_7	0 4	VPD	187 27	107.94	112.04	148.56	153.27	213.12
		LAI	0.278	1.068	1.276	1.063	0.623	0.249

Tillering stage:

At this stage, the ET and LAI of the treatment of IW/CPE of 1.0 was higher than that in the other treatments. The treatment with IW/CPE of 1.0, 0.9 and 0.8 showed PET of 44.08 mm and VPD of 124.4 mb which was more than that in the remaining treatments.

The treatment with IW/CPE of 1.0 showed more ET as compared to that with the treatments of IW/CPE of 0.9, 0.8 , 0.7 and 0.6, although these treatments also received one irrigation. This might be because the treatment with IW/CPE of 1.0 received irrigation earlier, i.e. on the 19^{th} day after sowing and therefore, produced comparatively more number of leaves and more leaf area. Hence, the evapotranspiration losses were more resulting in the highest ET.

Jointing Stage:

At this stage, the LAI (2.099) of the treatment with IW/CPE of 1.0 was the highest. The LAI (1.276) of IW/CPE of 0.4 was the lowest. The LAI was maximum at the jointing stage for all the treatments.

From the tillering to jointing stage, the ET (68mm) of IW/CPE of 1.0 was the highest and the ET (17mm) of IW/CPE of 0.4 was the lowest.

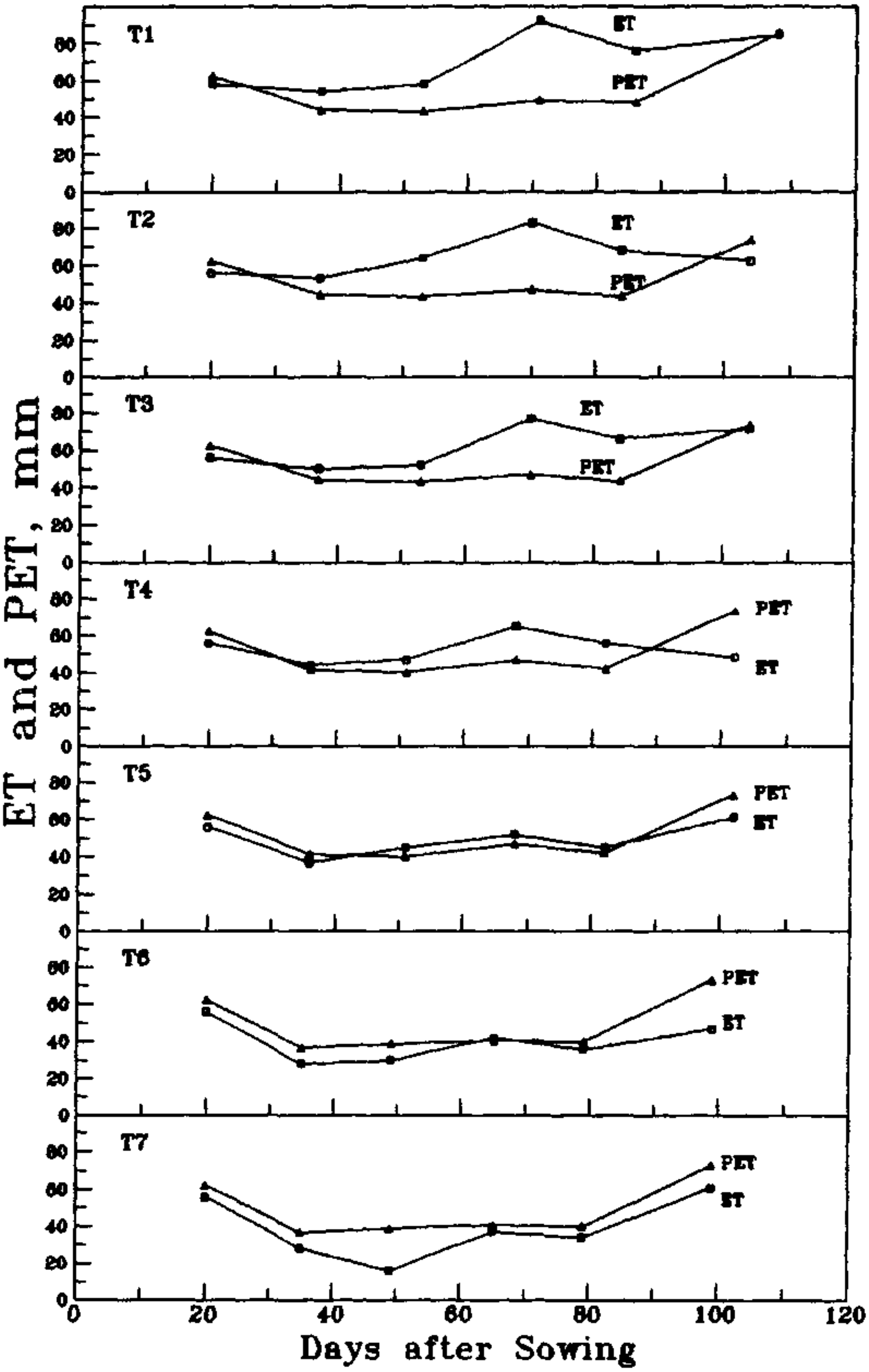

Fig. 13(a) ET (mm) and PET (mm) as per physiological growth stages of irrigation treatments

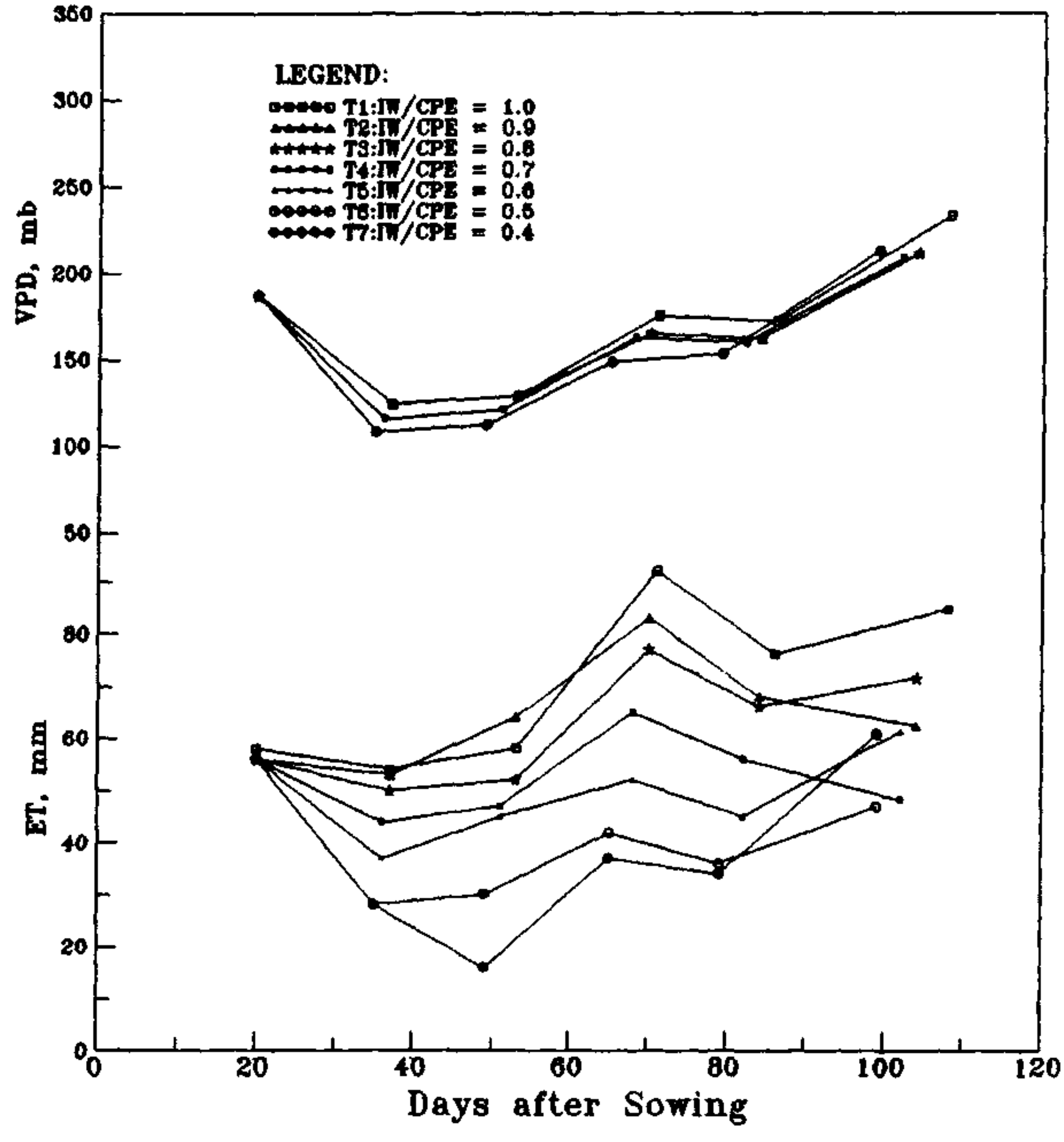

Fig. 13(b) ET (mm) and VPD (mb) as per physiological growth stages of irrigation treatments

The PET and VPD was the highest in IW/CPE of 1.0 and it was the lowest in the IW/CPE of 0.4.

This might be because up to the jointing stage, the treatments of IW/CPE of 1.0 to 0.5 were given at least one irrigation while IW/CPE of 0.4 did not receive even a single irrigation.

Flowering Stage:

At this stage LAI (1.619) of IW/CPE of 1.0 was the highest while LAI (1.063) of IW/CPE of 0.4 was the lowest.

From jointing to flowering stage, ET (92mm) of IW/CPE of 1.0 was the highest while ET (37mm) of IW/CPE of 0.4 was the lowest.

The treatment with IW/CPE of 1.0 showed PET (49.27mm) and VPD (175.52mb) which was higher than those in the other treatments.

This was because of the fact that up to flowering stage, IW/CPE of 1.0 was given three irrigations in advance as compared to two or one irrigation in the other treatments. The crop in this treatment was actively growing due to which it produced more leaf area resulting in more evapotranspiration losses.

Milk Stage:

At this stage, the LAI (1.107) of IW/CPE of 1.0 was the highest while LAI (0.623) of IW/CPE of 0.4 was the lowest.

From flowering to milk stage, the ET (76mm) of IW/CPE of 1.0 was the highest while ET (34mm) of IW/CPE of 0.4 was the lowest.

The treatment with IW/CPE of 1.0 showed PET (48.11mm) and VPD (172.02mb) which was the highest and IW/CPE of 0.4 showed PET (40.06mm) and VPD (153.27mb) which was the the lowest.

This was because of the fact that up to milk stage the IW/CPE of 1.0 received four irrigations while IW/CPE of 0.4 received only one irrigation.

Physiological Maturity:

At this stage, the LAI (0.307) of IW/CPE of 1.0 was the highest while LAI (0.249) of IW/CPE of 0.4 was the lowest.

From milk stage to physiological maturity stage the ET (84.6mm) of IW/CPE of 1.0 was the highest.

The treatment with IW/CPE of 0.9 showed less ET (62.3mm) than that of IW/CPE of 0.8 (71.5mm), though both of them were given four irrigations each. The treatment with IW/CPE of 0.7 showed less ET (48.2mm) than that of IW/CPE of 0.6 (61.2mm), though both of them were given three irrigations each. The treatment with IW/CPE of 0.5 showed less ET (46.9mm) than ET did IW/CPE of 0.4 (60.8mm), though both of them were given two irrigations each. This was because of fact that the period of receiving irrigations and attainment of physiological maturity stage was less in the treatments with IW/CPE of 0.8, 0.6 and 0.4 but their per day ET was more. Because, during this period the temperature was maximum and windy conditions prevailed. Therefore, they showed more ET than did the IW/CPE of 0.9, 0.7 and 0.5 treatments, respectively.

In general, the average ET per day was initially less during emergence to tillering stage, increased up to grain formation stage and then decreased towards physiological maturity stage. These results are in agreement with the results obtained by Janna and Sen (1978) and Singh (1987).

Figure 11(a) to 11 (b) show that with increase in VPD the ET and PET increased. This was because the difference between dry bulb and wet bulb temperature was more. Due to higher air temperature, the loss of water from soil and plant was more which resulted in more ET.

Evapotranspiration (ET) v/s leaf area index (LAI):

It would be clear from the Fig. 14 that the leaf area index increases with increase in evapotranspiration up to jointing stage, i.e. from 49th to 53rd after sowing and decreased thereafter for all the treatments. Similar results were reported by Mathur (1966), Choudhari (1978) and Jadhav (1989).

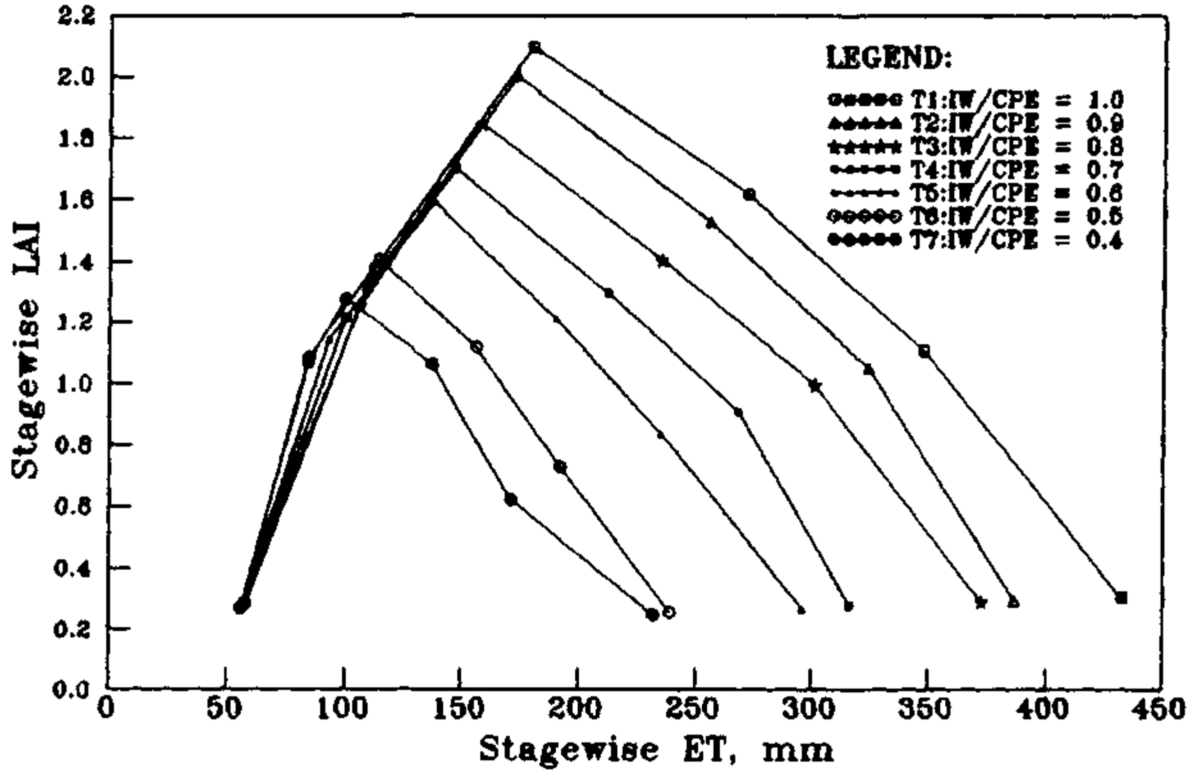

Fig. 14 ET v/s LAI as per physiological growth stages of irrigation treatments

4.9 WEEKLY ET (mm), PET (mm), AND VPD (mb) FOR IRRIGATION TREATMENTS:

The data regarding weekly ET, PET and VPD of the different irrigation treatments are presented in Table 17 and graphically shown in Fig. 15

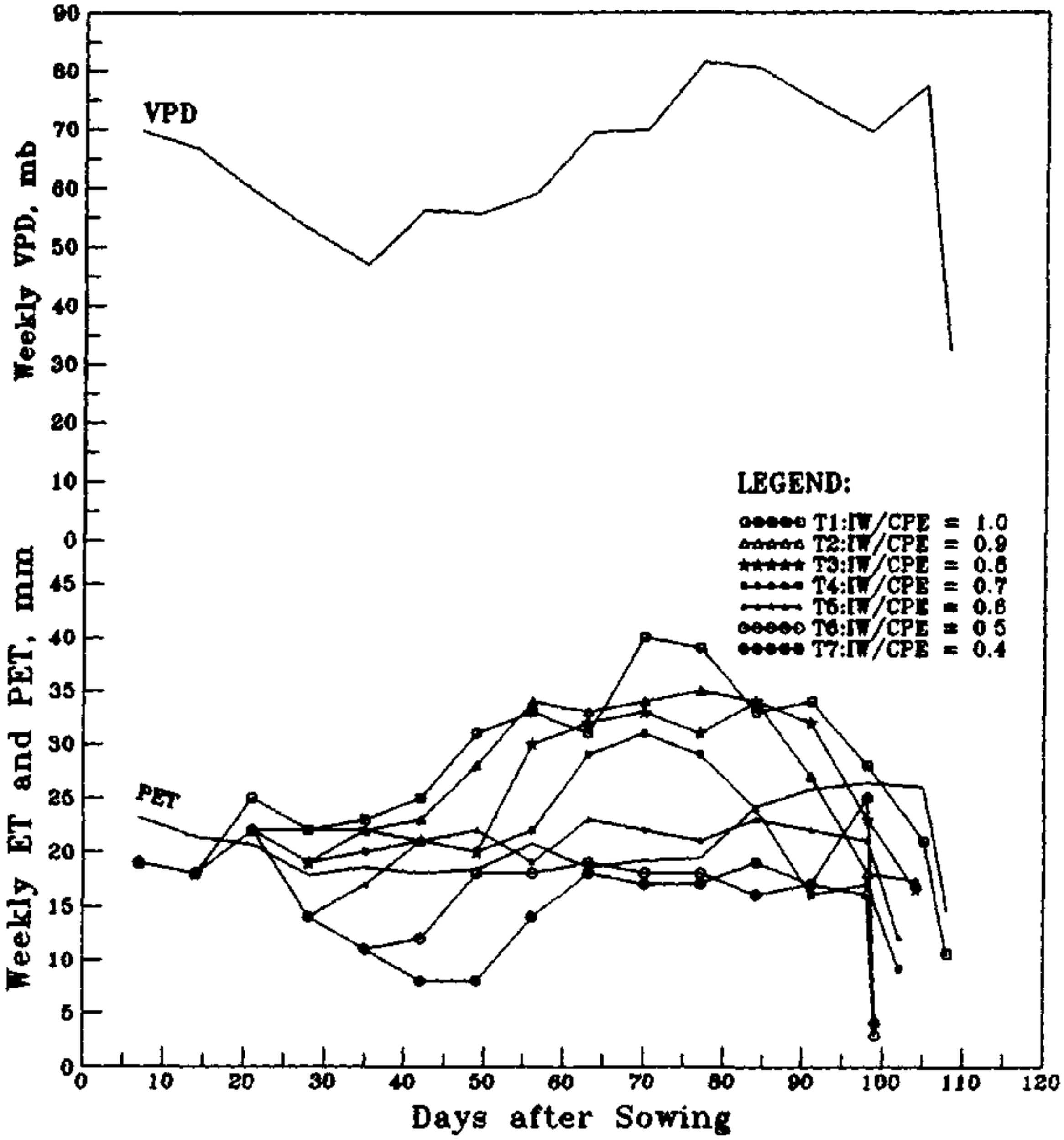

Fig. 15 Weekly ET (mm), PET (mm) and VPD (mb) for irrigation treatments.

Table 17 Weekly ET (mm), PET (mm) and VPD (mb) for different treatments

week No.	Date	Evapotranspiration (mm)							PET(mm)	VPD(mm)
		T_1	T_2	T_3	T_4	T_5	T_6	T_7		
1	16-11 to 22-11-89	19	19	19	19	19	19	19	23.18	69 66
2	23-11 to 29-11-89	18	18	18	18	18	18	18	21.40	66.67
3	30-11 to 06-12-89	25	22	22	22	22	22	22	20.64	59 28
4	07-12 to 13-12-89	22	22	19	19	14	14	14	17 84	52.70
5	14-12 to 23-12-89	23	22	22	20	17	11	11	18.54	46.93
6	21-12 to 27-12-89	25	23	21	21	21	12	8	18.04	56.36
7	28-12 to 03-01-89	31	28	20	20	22	18	8	18.35	55.68
8	04-01 to 10-01-90	33	34	30	22	19	18	14	20.76	58.93
9	11-01 to 17-01-90	31	33	32	29	23	19	18	18 54	69.46
10	18-01 to 24-01-90	40	34	33	31	22	18	17	19.21	69.88
11	25-01 to 31-01-90	39	35	31	29	21	18	17	19.32	81.45
12	01-02 to 07-02-90	33	34	34	24	23	16	19	24 20	80 54
13	08-02 to 14-02-90	34	27	32	16	22	17	17	25 85	74.88
14	15-02 to 21-02-90	28	18	23	17	21	16	25	26 37	69.40
15	22-02 to 28-02-90	21	17.3	16.5	09.2	12 1	02.9	04.1	25.96	77 41
16	01-03 to 03-03-90	10.6	-	-	-	-	-	-	14.58	32.50

Weekly evapotranspiration (ET):

The treatment with IW/CPE of 1.0 produced on an average more evapotranspiration for all the weeks in the crop growth period. Weekly ET for the treatments with IW/CPE of 0.9 and 0.8 was more or less the same, but slightly less than that of the treatment with IW/CPE of 1.0.

The treatments with IW/CPE of 0.7 and 0.6 had their ET more or less on par with each other but less than that of IW/CPE of 0.9 and 0.8. The treatments with IW/CPE of 0.5 and 0.4 had their ET again at par with each other, but less than that of IW/CPE of 0.7 and 0.6.

This might be because the treatments with IW/CPE of 1.0 received five irrigations; the treatments with IW/CPE of 0.9 and 0.8 received four irrigations; the treatments with IW/CPE of 0.7 and 0.6 received three irrigations and the treatments with IW/CPE of 0.5 and 0.4 received only two irrigations during the crop growth period.

Weekly potential evapotranspiration (PET):

PET was initially (about two weeks) more than ET. After that, it ranged between the ET of IW/CPE of 1.0 and 0.4. Towards physiological maturity stage again PET was more than the ET. This is due to the fact that the PET is governed by meteorological parameters and the ET depends upon crop stage, soil moisture and climatic conditions. AT early stages of crop growth, the rate of growth is low and the land is not fully covered. This caused low ET at early stage. As crop grows, leaf area increases and there is increase in ET. At physiological maturity crop growth ceases, leaves dry and hence low ET than PET.

Weekly vapour pressure deficit (VPD):

Initially, the weekly VPD was more and then it went on decreasing upto the 7th week (i.e. 46.93 mb) and again increased upto the 11th week (i.e. 81.45 mb). From the 12th onwards, it decreased upto the 14th week and again it increased.

Fig. 13 shows that with increase in VPD, the ET and PET increased and with decrease in VPD, the ET and PET decreased. Increase in VPD means there was an increased atmospheric demand which increased the ET and PET and decreased in VPD means there was a decreased atmospheric demand which decreased the ET and PET.

4.10 PLANT POPULATION:

The data on plant population per meter length was collected on the 15th day after sowing and at physiological maturity stage. The data is presented in

Table 18. The initial and final plant population was not affected by the various treatments.

Table 18 Initial plant population (15 days after sowing) and final plant population (at physiological maturity) for irrigation treatments

Treatment No.	IW/CPE ratio	Initial plant population	Final plant population
T_1	1.0	51.50	50.00
T_2	0.9	52.00	49.50
T_3	0.8	51.50	50.50
T_4	0.7	51.00	49.50
T_5	0.6	52.00	49.00
T_6	0.5	51.50	48.50
T_7	0.4	52.00	47.50

4.11 GROWTH STUDIES:

4.11.1 Plant Height:

The plant height (shoot length) generally indicates the vigour and growth of the plant. The data regarding the plant height were recorded at the different physiological stages. In all the treatments a major increase in the height of the main shoot was observed from crown root initiation to milk stage whereas a slight increase in height was observed between milk stage and physiological maturity stage. The effects of irrigation treatments on plant height are presented in Table 19 and are graphically shown in Fig. 16

Table 19 Mean height of plant (cm) at different growth stages as affected by irrigation treatments

Treatment	IW/CPE ratio	Crown root	Tillering	Jointing	Flowering	milk	physiological maturity
T_1	1.0	4.71	12.43	43.60	59.80	72.48	75.03
T_2	0.9	4.70	12.47	41.42	58.73	70.35	73.24
T_3	0.8	4.67	12.26	41.25	57.53	69.23	72.69
T_4	0.7	4.69	11.87	40.82	56.85	67.31	70.97
T_5	0.6	4.66	11.80	40.63	53.83	63.48	65.53
T_6	0.5	4.66	11.35	38.10	51.34	63.07	65.47
T_7	0.4	4.67	11.22	37.90	50.85	61.93	64.77

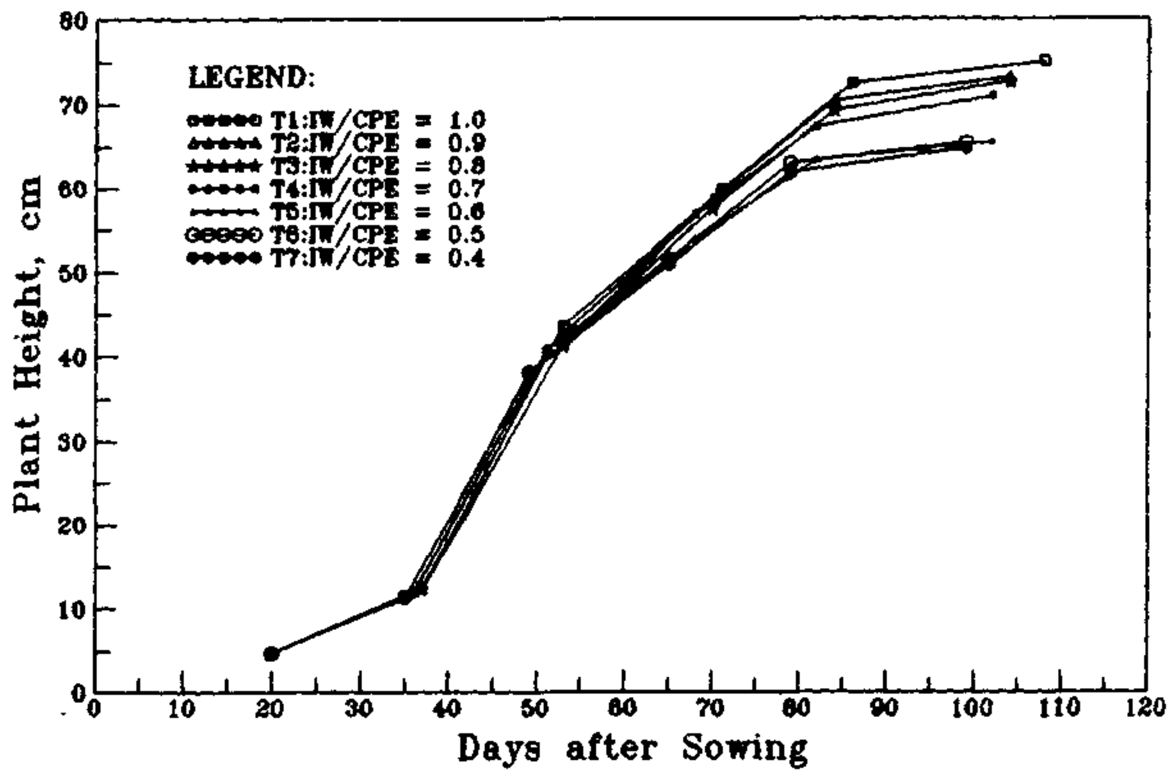

Fig. 16 Mean height of plant (cm) as affected by irrigation treatments

Growth observations on height indicated that the height of wheat plant was not affected due to the different irrigation treatments upto 20 days after sowing i.e. up to the crown root initiation stage. This was due to the fact that the soil moisture status was adequate in all the treatments under study. But at the tillering stage (35 to 37 days after sowing), it was observed that the treatments with IW/CPE of 1.0, 0.9, 0.8 and 0.6 which received one irrigation before the tillering stage had attained showed more height than did the treatments with IW/CPE of 0.5 and 0.4 which did no receive any irrigation.

The observations recorded at jointing stage show much increase in height of the treatment with IW/CPE of 1.0 as compared to that with the other treatments. The treatments with IW/CPE of 0.9 and 0.8 shows a slightly less increase in height as compared to that with IW/CPE of 1.0; but was greater than that with IW/CPE of 0.7, 0.6, 0.5 and 0.4. At the flowering stage, the variation in height in all the treatments were obvious. By then, all the treatments received either different number of irrigations or if the same number of irrigations, they were at different time.

At milk stage, the IW/CPE of 1.0 showed the highest shoot length because it received three irrigations upto this stage and the IW/CPE of 0.4 showed minimum shoot length as it received only one irrigation till then. Upto physiological maturity, IW/CPE of 1.0 received five irrigations, the treatment with IW/CPE of 0.9 and 0.8 received four irrigations, the treatments with IW/CPE of 0.7 and 0.6 received three irrigations and the treatments with IW/CPE of 0.5 and 0.4 received only two irrigations. Amongst all the treatments the IW/CPE of 1.0 showed the highest shoot length, whereas the IW/CPE of 0.4 showed the lowest shoot length. This might be because, the IW/CPE of 1.0 received timely irrigations near about crown root initiation and tillering stage, whereas IW/CPE of 0.4 did not receive irrigation near about these two stages. The treatments with IW/CPE of 0.9, 0.8, 0.7, 0.6 and 0.5 showed their shoot length ranging between those of the treatments with IW/CPE of 1.0 and 0.4.

Thus, it was observed that the crop height was, by and large, directly related to the number of irrigations received by the crops. It further showed that irrigations need to be given at the crown root initiation and tillering stages. As per IW/CPE ratio, it will be seen that shoot length was in proportion with the increase in the IW/CPE ratio and hence irrigations scheduled at IW/CPE of 1.0 gave the highest shoot length. The results are in conformity with the findings of Prashar and Singh (1963), Shrotriya et al. (1970), Patel et al. (1971), Tommer (1976) and Sambasiva Rao (1982).

4.11.2 Number of Functional Leaves Per Plant:

The data for the number of functional leaves per plant as affected by the different treatment are presented in Table 20 and are graphically shown in Fig. 17

The data show that the number of functional leaves per plant in all the treatments was increased from germination to jointing stage (i.e. upto the 49^{th} to 53^{rd} days after sowing). Thereafter, the lower leaves started drying and the number of functional leaves per plant decreased. The difference in the number of functional leaves due to the different treatments varied from the tillering stage to the physiological maturity stage.

It will also be evident from the data that the number of functional leaves at jointing stage (i.e. 53^{rd} days after sowing was the highest in the case of the treatment with IW/CPE of 1.0 which received two irrigations upto this stage. The number of functional leaves of the treatments with IW/CPE of 0.9 and 0.8 at jointing stage was less than that of the treatment with IW/CPE of 1.0 although

Table 20 Mean number of functional leaves per plant as affected by different irrigation treatments

Treatment	IW/CPE ratio	Crown root	Tillering	Jointing	Flowering	milk	physiological maturity
T_1	1.0	4.7	11.5	14.8	12.6	6.9	2.1
T_2	0.9	4.3	10.3	13.9	11.3	6.3	1.9
T_3	0.8	4.2	10.0	13.5	11.1	6.2	1.7
T_4	0.7	4.3	9.9	12.6	10.8	5.8	1.4
T_5	0.6	4.4	9.5	12.2	10.3	5.3	1.1
T_6	0.5	4.0	9.2	11.7	10.1	4.8	0.9
T_7	0.4	4.1	8.9	11.4	9.7	4.3	0.6

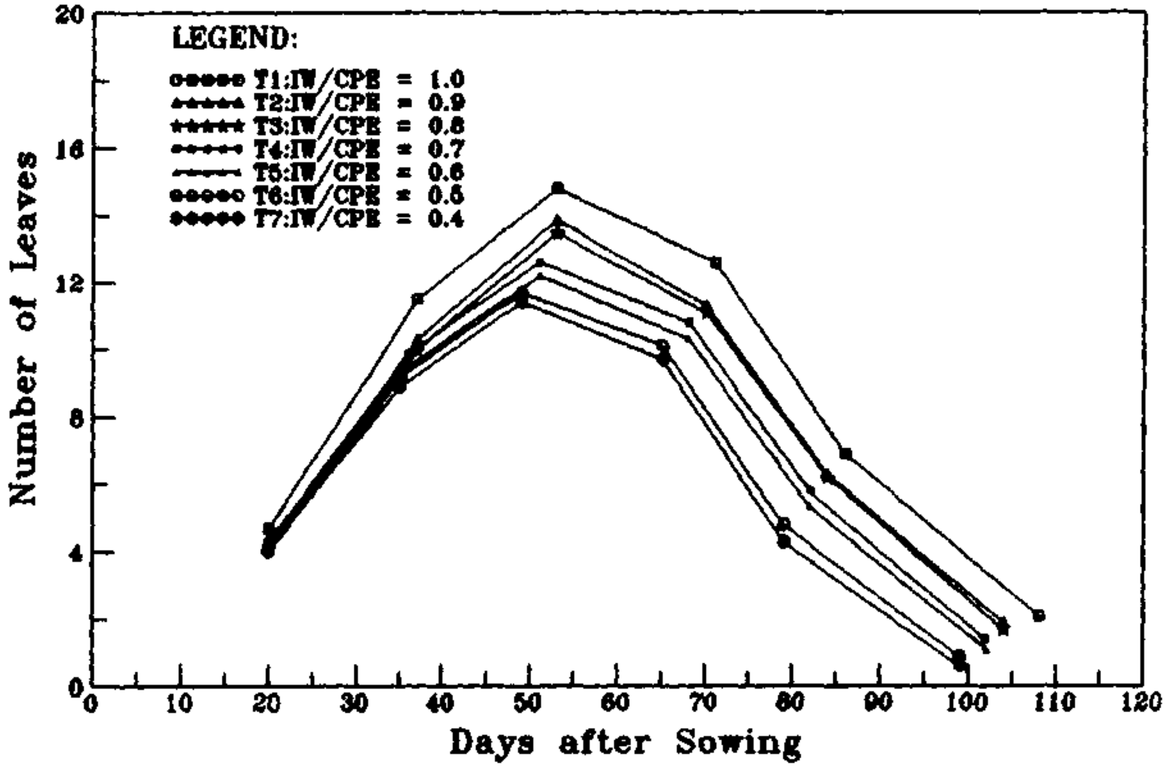

Fig. 17 Mean number of functional leaves per plant as affected by irrigation treatments

they also received two irrigations upto the jointing stage. This might be because IW/CPE of 1.0 received these irrigations quite earlier. The treatment with IW/CPE of 0.4 showed the lowest number of functional leaves at jointing stage, as it did not receive any irrigation till this stage. The treatments with IW/CPE of 0.6 and 0.5 showed intermediate number of functional leaves as they received one irrigation upto jointing stage.

It will also be evident from the Table 20 that the leaves continued to function and remained green for a longer period, if the crop had adequate moisture. The crop with inadequate moisture dried earlier. Also from the critical stage point of view, the application of irrigations near crown root initiation and late tillering stage was important to increase the number of functional leaves per plant.

Thus, in general IW/CPE of 1.0 showed the highest nubmer of functional leaves and IW/CPE of 0.4 showed the lowest number of functional leaves at all the stages of experimentations.

4.11.3 Leaf Area [LA(sq.cm)] and Leaf Area Index (LAI) Per Plant of Wheat Crop:

The data regarding the leaf area per plant and leaf area index of wheat as affected by the various treatments are presented in Table 21 and graphically shown in Fig. 18

It would be seen from the data, that the leaf area per plant gradually increased from the germination to jointing stage (i.e. 49^{th} to 53^{rd} days after sowing) and decreased thereafter upto the physiological maturity. The same trend was observed in the leaf area index also.

The treatment with IW/CPE of 1.0 showed the highest leaf area and leaf area index as compared to that due to the other treatments at all the crop stages.

The treatment with IW/CPE of 0.4 showed the lowest leaf area and the leaf area index. The treatments with IW/CPE of 0.9, 0.8, 0.7. 0.6 and 0.5 were intermediate in their effect.

Table 21 Leaf area [LA (sq.cm)] and leaf area index (LAI) per plant as affected by different irrigation treatments

Treatment		T_1	T_2	T_3	T_4	T_5	T_6	T_7
IW/CPE ratio		1.0	0.9	0.8	0.7	0.6	0.5	0.4
CRI	LA	32.46	31.10	30.85	31.30	30.80	30.90	30.70
	LAI	0.288	0.276	0.274	0.278	0.274	0.275	0.272
Tillering	LA	155.20	148.31	141.04	136.50	128.50	122.17	120.03
	LAI	1.379	1.318	1.253	1.213	1.142	1.085	1.068
Jointing	LA	236.16	225.5	208.06	191.60	179.53	158.15	143.60
	LAI	2.099	2.004	1.849	1.703	1.595	1.405	1.276
Flowering	LA	182.15	172.11	158.02	146.002	136.13	126.10	119.63
	LAI	1.619	1.529	1.404	1.297	1.210	1.120	1.063
Milk	LA	124.62	118.22	112.13	102.16	94.07	82.04	70.17
	LAI	1.107	1.050	0.996	0.908	0.836	0.729	0.623
Maturity	LA	34.40	33.40	32.80	31.60	30.20	28.80	28.00
	LAI	0.306	0.297	0.292	0.281	0.268	0.256	0.249

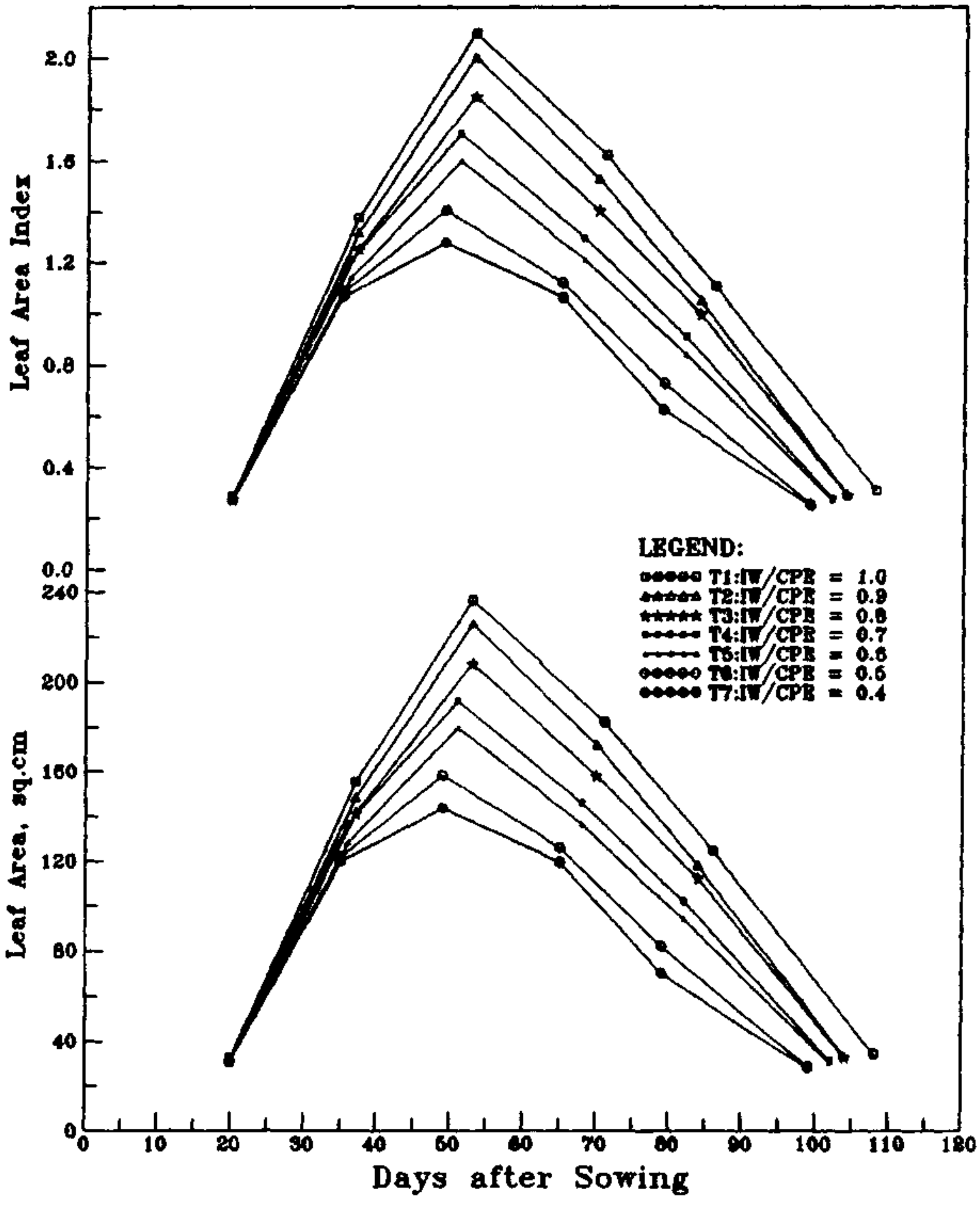

Fig. 18 Leaf area [LA (cm^2)] and Leaf area index per plant as affected by irrigation treatments

In general, this might be due to the fact that the leaf area and leaf area index increased in proportion to the increase in IW/CPE ratio and ultimately the number of irrigations. Amongst the critical stages, crown root initiation and late tillering were observed to be critical in respect of this attribute. The treatment with IW/CPE of 1.0 which received five irrigations prior to the physiological stages, produced the highest leaf area. The treatments with IW/CPE of 0.9, 0.8 and 0.7 also correlated number of irrigations to physiological growth stages and showed the higher leaf area than the remaining treatments. The treatment with IW/CPE of 0.4 received only two irrigations which were ill timed. Hence, it produced the lowest leaf area index.

4.11.4 Number of Tillers Per Plant:

The data pertaining to the number of tillers per plant as affected by the different treatments at the different stages of crop growth are presented in Table 22 and graphically depicted in Fig. 19

It would be seen from the data that the number of tillers per plant increased from thee tillering stage upto the jointing stage and decreased thereafter upto maturity. This might be because sometimes after jointing stage the mortality starts.

The treatments with IW/CPE of 1.0, 0.9, 0.8, 0.7 and 0.6 which were given irrigation before tillering stage showed the higher number of tillers at the jointing stage than did the treatments with IW/CPE of 0.5 and 0.4 which were not given any irrigation till the jointing stage.

The treatments with IW/CPE of 1.0, 0.9, 0.8, 0.7 and 0.6 were given first irrigation on the 18th day, 16th day, 13th day and 5th day, respectively in advance of the tillering stage. Due to this, these treatments showed inter-treatment variations in the number of tillers upto tillering stage.

Table 22 Mean number of tillers per plant at different growth stages as affected by irrigation treatments

Treatment	IW/CPE	Tillering	Jointing	Flowering	Milk	Maturity
T[1]	1.0	2.9	3.6	3.1	2.6	1.9
T_2	0.9	2.9	3.5	3.0	2.5	1.7
T_3	0.8	2.8	3.5	2.9	2.4	1.6
T_4	0.7	2.7	3.4	2.9	2.1	1.5
T_5	0.6	2.7	3.2	2.7	1.8	1.5
T_6	0.5	2.3	2.9	2.4	1.7	1.2
T_7	0.4	2.1	2.6	2.2	1.6	1.1

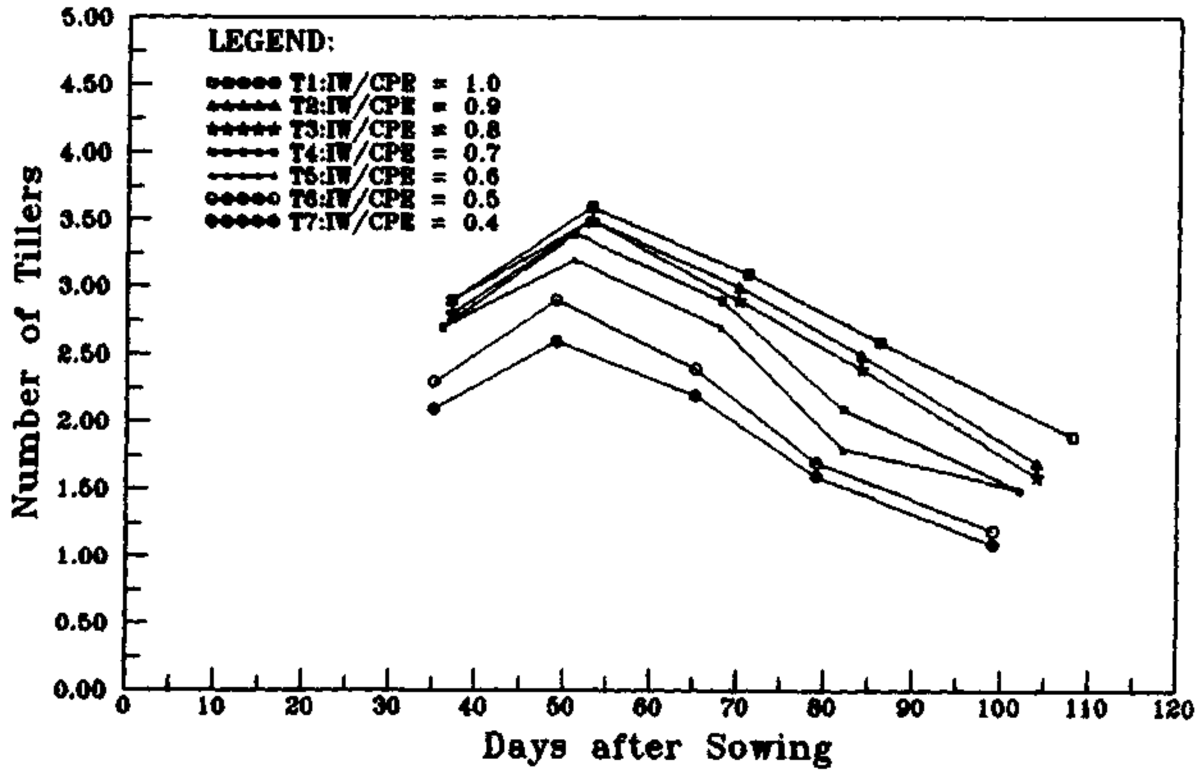

Fig. 19 Mean number of tillers per plant as affected by irrigation treatments

The treatments with IW/CPE of 1.0 and 0.9 had the number of tillers 2.9 each while the treatments with IW/CPE with 0.8, 0.7 and 0.6 had 2.8, 2.7 and 2.7 number of tillers, respectively upto the tillering stage.

At the jointing stage also, the highest number of tillers was observed in IW/CPE of 1.0 and the lowest number of tillers was observed in IW/CPE of 0.4. The other treatments had the number of tillers in between the number of tillers of above two treatments.

The treatments with IW/CPE of 1.o and 0.9 were given their first irrigation on the 19th and 21st day, respectively after sowing. As these two treatments were given irrigation near crown root initiation stage (which comes on the 20th day after sowing) they showed more number of tillers per plant as compared to other treatments.

Thus, in case of wheat, it is essential to give irrigation approximately at crown root initiation stage around 20 days after sowing which results afterwards in the increase of number of tillers per plant and thereby increases the productivity per plant. These results are similar to those reported by Gautam et al. (1968), Varma (1970), Jana and Sen (1978) and Stark and Langely (1986).

4.11.5 Dry Matter Accumulation Per Plant:

The effect of irrigation the treatments viz. IW/CPE of 1.0 to 0.4production of dry matter per plant was studied in the present investigation and the data are presented in Table 23 and graphically shown in Fig. 20

It would be observed from the data that there was no difference in the per plant dry matter produced up to the crown root initiation (20 days after sowing). The observation recorded at the tillering stage (35 to 37 day after sowing) also showed a similar trend. However, at the subsequent stages, that is from the jointing to physiological maturity stage there were differences in the dry matter production per plant.

Table 23 Dry matter per plant (gm) at different growth stages as affected by irrigation treatments

Treatment	IW/CPE ratio	Crown root	Tillering	Jointing	Flowering	milk	physiological maturity
T_1	1.0	0.178	0.573	1.950	3.615	4.755	5.986
T_2	0.9	0.175	0.568	1.906	3.583	4.640	5.720
T_3	0.8	0.176	0.564	1.845	3.527	4.590	5.510
T_4	0.7	0.173	0.557	1.780	3.370	4.250	5.320
T_5	0.6	0.174	0.552	1.742	3.220	4.130	4.780
T_6	0.5	0.175	0.547	1.660	2.975	3.320	3.670
T_7	0.4	0.176	0.541	1.440	2.765	3.010	3.215

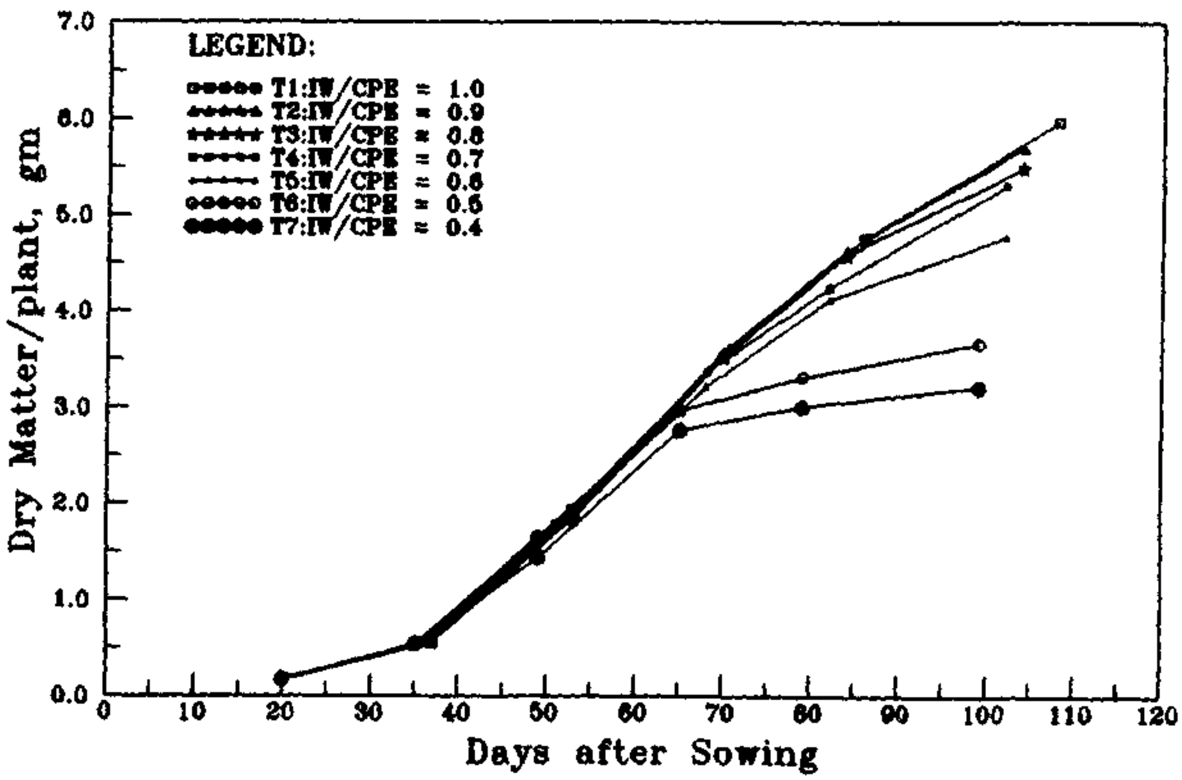

Fig. 20 Dry matter per plant (gm) as affected by irrigation treatments

At the physiological maturity stage, the observations indicated that the the treatment with IW/CPE of 1.0, which was given five irrigations produced the highest amount of dry matter per plant. The treatments with IW/CPE of 0.9 and 0.8 which received four irrigations, showed a similar trend at all the stages. The treatments with IW/CPE of 0.7 and 0.6 which received three irrigations each did not show any inter–treatment differences in the dry matter produced per plant at the different growth stages. The treatments with IW/CPE of 0.5 and 0.4 which received two irrigations each showed the same trend at all the stages. The treatment with IW/CPE of 0.4 produced the lowest amount of dry matter per plant.

The results indicated that during the early growth period of a crop, the dry matter production per plant was not much influenced by the different treatments; but subsequently at all the growth stages the dry matter production per plant increased with an increase in the number of irrigations. This increase in dry matter production per plant could be attributed to the increase in height, number of functional leaves and number of tillers per plant. The maintenance of higher soil moisture in the root zone due to more number of irrigations seems to have helped in enhancing these characters and ultimately in reflectingthe dry matter production.

Thus, for more dry matter production it is required to maintain higher soil moisture during vegetative growth period. From the view point of irrigations, applications at early stages i.e. near crown root initiation and tillering stages were found to be most important. These results are similar to those reported by Prashar and Singh (1963) and Pandey (1986)

4.11.6 Number of Days Required for Maturity:

The data regarding the number of days required for maturity of crop as influenced by the different irrigation treatments are given in Table 24 and graphically shown Fig. 21

It will be evident form the data that the differences in the number of days required for maturity of crop in the different irrigation treatments were different during the experiment.

The results showed that as the number of irrigations decreased the maturity was enhanced. Thus, the maturity was earlier in the treatment with IW/CPE of 0.4 and 0.5 which were given only two irrigations than in the treatments with IW/CPE of 0.6, 0.7, 0.8, 0.9 and 1.0 which were given three, three, four, four and five irrigations, respectively.

Table 24 Date of sowing and dates of physiological maturity as affected by irrigation treatments

Treatment No.	IW/CPE ratio	Date of sowing	Date of physiological maturity	Days required for physiological maturity
T_1	1.0	16-11-89	03-03-90	108
T_2	0.9	16-11-89	27-02-90	104
T_3	0.8	16-11-89	27-02-90	104
T_4	0.7	16-11-89	25-02-90	102
T_5	0.6	16-11-89	25-02-90	102
T_6	0.5	16-11-89	22-02-90	99
T_7	0.4	16-11-89	22-02-90	99

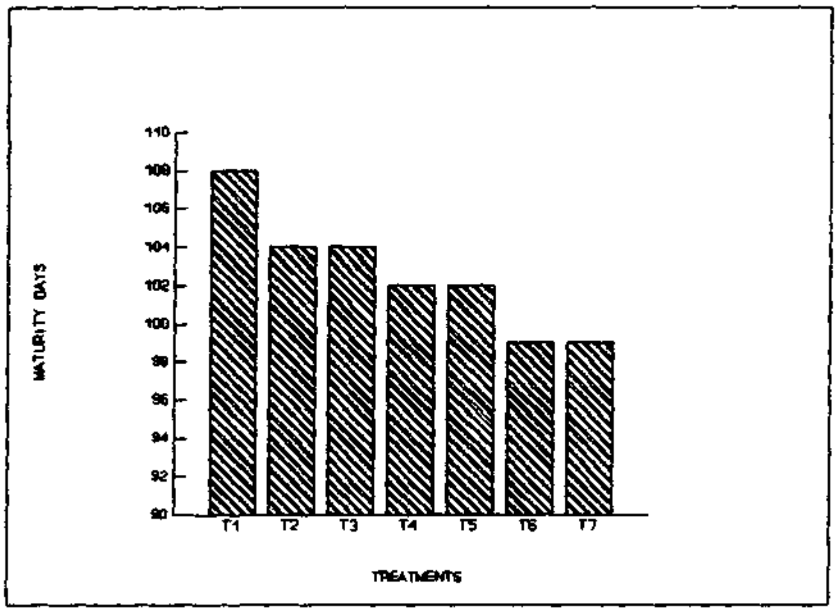

Fig. 21 Number of days required for maturity as affected by irrigation treatments

From this, it can be concluded that the less number of irrigations subjected plants to stress and they tried to complete their life cycle earlier.

4.12 YIELD CONTRIBUTING CHARACTERS:

4.12.1 Length of Earhead:

The data regarding length of earhead as affected by the different treatments are presented in Table 25 and graphically shown in Fig. 22

Table 25 Mean yield contributing characters as affected by irrigation treatments

Treat-ment No.	IW/CPE ratio	Length of earhead	Functional Spikelet/ earhead (cm)	No. of grains/ earhead	Grain weight/ earhead (gm)	Thousand grain weight (gm)
T_1	1.0	8.73	16	35	1.875	40.90
T_2	0.9	8.38	14	34	1.825	39.05
T_3	0.8	8.23	14	34	1.788	38.95
T_4	0.7	8.03	13	33	1.715	38.30
T_5	0.6	7.82	11	29	1.432	36.13
T_6	0.5	7.40	9	26	1.367	32.40
T_7	0.4	7.07	8	24	1.213	29.65

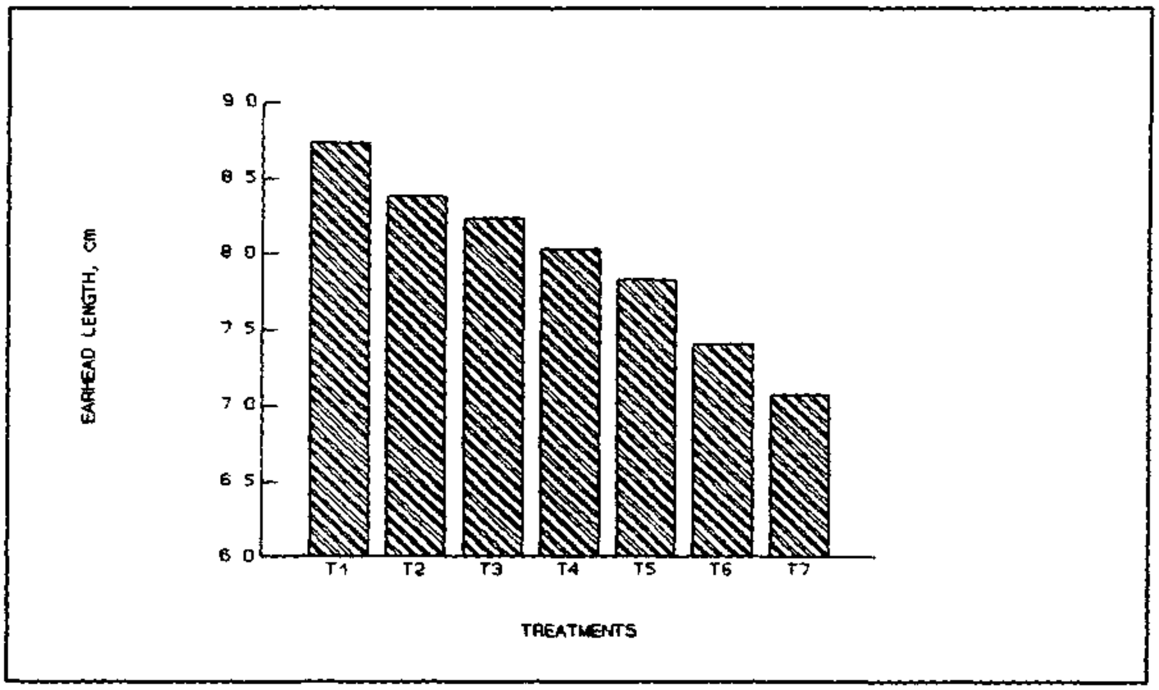

Fig. 22 Length of earhead (cm) as affected by irrigation treatments

It will be evident from the data that the mean length of earhead showed inter-treatment differences.

The treatment with IW/CPE of 1.0 which received five irrigations, i.e. on the 19th, 39th, 61st, 78th and 94th day after sowing, produced earheads of the highest length. The treatments with IW/CPE of 0.9 and 0.8 which were given four irrigations and the treatments with IW/CPE of 0.7 and 0.6 which were given three irrigations were intermediate in their effect. The treatments with IW/CPE of 0.5 and 0.4 which were given two irrigations did not show much difference in the length of earhead. However, the IW/CPE of 0.4 which was given irrigations on the 52nd and 94th day after sowing, produced earheads of the lowest length.

Thus, it would be clear that the frequency of irrigations substantially affected the earhead length. These results are similar to those reported by Sekhon (1968), Patel et al. (1971), Jana and Sen (1978) and Stark and Langely (1986).

4.12.2 Functional Spikelet Number Per Earhead:

The data in respect of number of functional spikelets per earhead in the various treatments are presented in Table 25 and graphically shown in Fig. 23

The number of functional spikelets per earhead increased with increase in the number of irrigations. Irrigations received for IW/CPE of 1.0 produced the highest number of effective functional spikelets. The functional spikelets number produced by the treatments with IW/CPE of 0.9 and 0.8 had a small inter-treatment variability. The values of the treatment with IW/CPE of 0.7 also came closer to the values of the treatments with IW/CPE of 0.9 and 0.8. The treatments with IW/CPE of 0.6, 0.5 and 0.4 expressed a high inter-treatment variability. The treatment with IW/CPE of 0.4 produced the lowest number of functional spikelets per earhead.

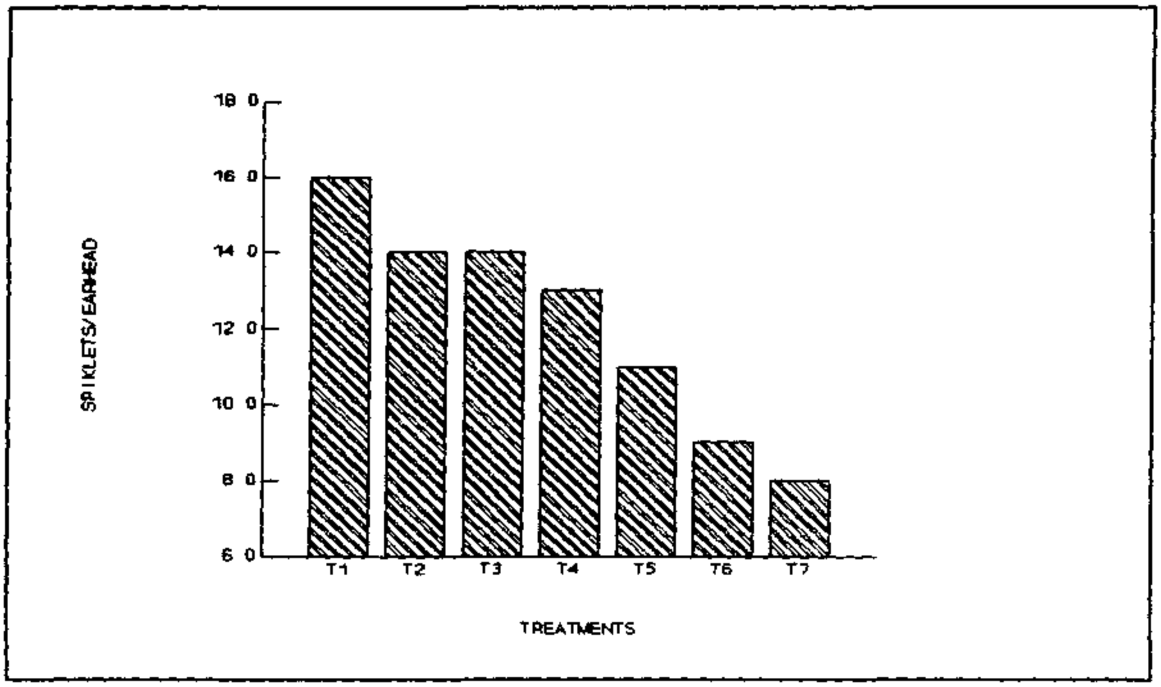

Fig. 23 Functional spiklet numbers per earhead as affected by irrigation treatments

Thus, the results indicated that the number of functional spikelets was a direct function of soil moisture status and thereby of the number of irrigations given to the crop. These results are similar to those reported by Shrotriya (1970), Jana and Sen (1978), Sharma (1981) and Ashok Kumar (1986).

4.12.3 Grain Number Per Earhead:

The number of grains per earhead as affected by the different treatments are presented in Table 25 and graphically presented in Fig. 24

It will be obvious from the data that the mean number of grains per earhead was affected by the various irrigation treatments based on the different IW/CPE ratios.

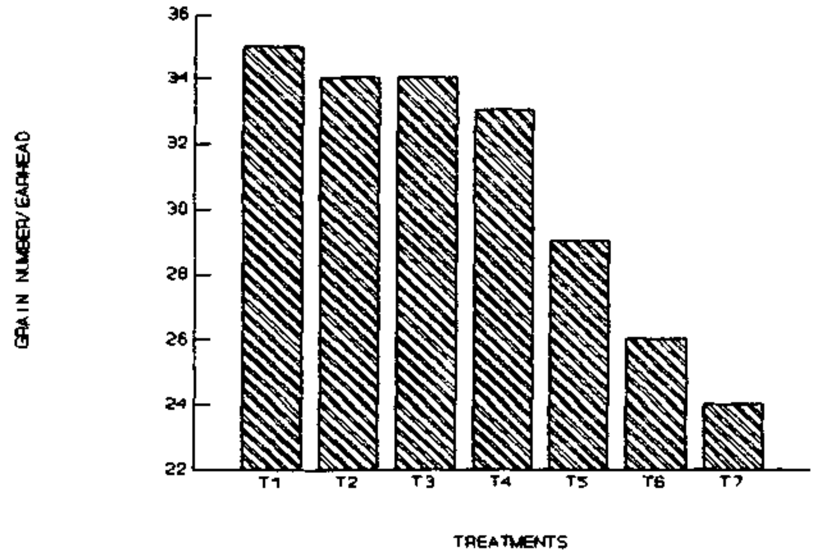

Fig. 24 Grain number per earhead as affected by irrigation treatments

The treatments with IW/CPE of 1.0 and 0.9 in which first irrigation was applied near crown root initiation stage, i.e. on the 19th and 21st day after sowing, produced a maximum number of grains. The treatments with IW/CPE of 0.8 and 0.7 were intermediate in their effect. The treatments with IW/CPE of 0.6, 0.5 and 0.4 produced a less number of grains per earhead.

The treatment with IW/CPE of 1.0 produced the higher number of grains per earhead. The treatment with IW/CPE of 0.4 produced the lowest number of grains per earhead because it was given only two irrigations during the total crop growth period out of which first irrigation was given very late, i.e. on the 52nd day after sowing as per IW/CPE ratio.

Thus, the results showed that in general the grain number per earhead increased with increase in irrigations. These results are in conformity with those of Patel et al. (1971), Jana and Sen (1978), Sharma (1981), Prabhakar (1981) and Ashok Kumar (1986).

4.12.4 Grain Weight Per Earhead:

It will be obvious from the data tabulated in Table 25 and graphically shown in Fig. 25 that the mean grain weight per earhead was affected by the different treatments.

It will also be obvious from the data that the mean grain weight per earhead was affected by the different treatments.

The grain weight per earhead was the highest in the treatment with IW/CPE of 1.0 which received five irrigations. The treatments with IW/CPE of 0.9 and 0.8 showed a higher grain weight than did the treatments with IW/CPE of 0.7 and 0.6. The treatments with IW/CPE of 0.5 and 0.4 showed the less grain weight per earhead as compared to that with all the other treatments. The treatment with IW/CPE of 0.4 showed the lowest grain weight per earhead.

Thus, results indicated that stress in earlier days, i.e. near crown root initiation and tillering stages reduced the grain weight per earhead. These results are similar to those obtained by Prashar and Singh (1963).

4.12.5 Thousand Grain Weight:

The data regarding mean thousand grain weight as affected by the different treatments are given in Table 25 and graphically shown in Fig. 26

It would be seen from the data, that the mean thousand grain weight was influenced by the various treatments. The mean thousand grain weight was in decreasing order with decreasing IW/CPE ratio. Hence, the treatment with IW/CPE of 1.0 which was given five irrigations showed the highest thousand grain weight while IW/CPE of 0.4 which was given only two irrigations showed the least value of thousand grain weight.

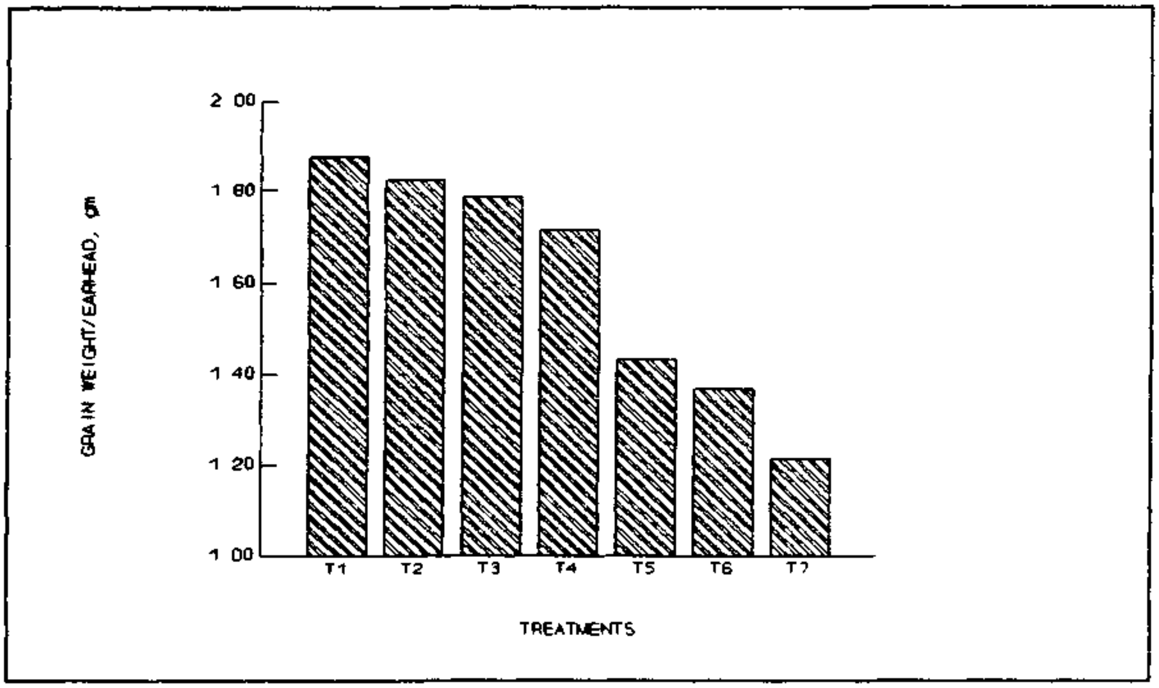

Fig. 25 **Grain weight per earhead (gm) as affected by irrigation treatments**

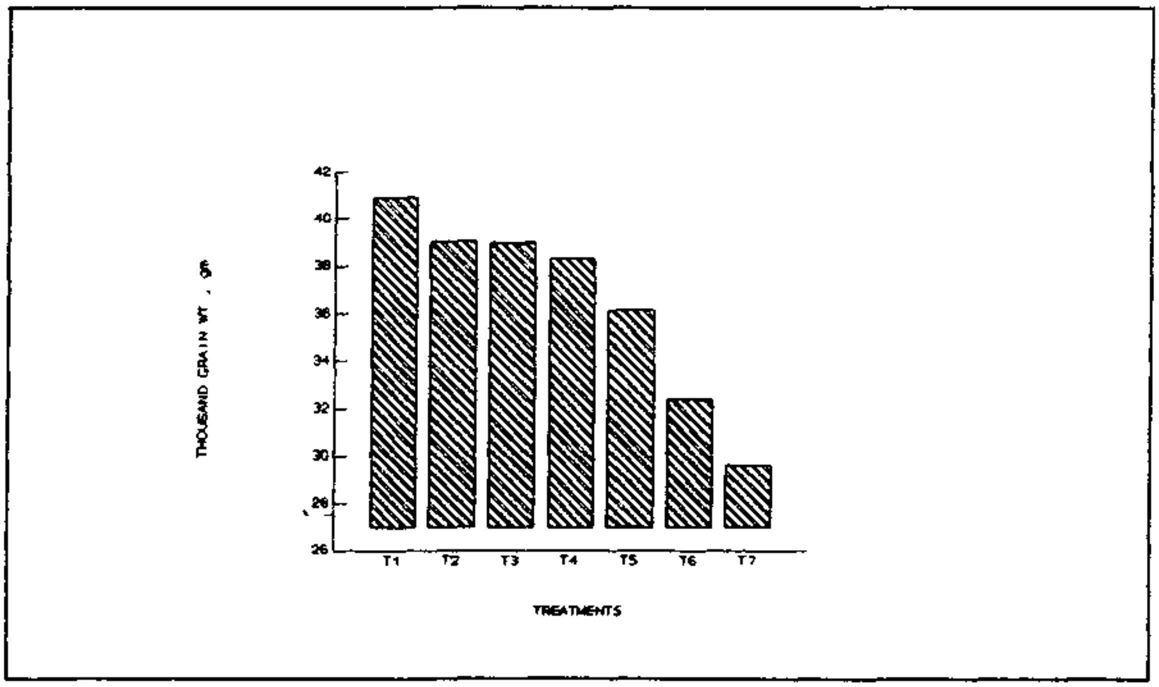

Fig. 26 **Thousand grain weight (gm) as affected by irrigation treatments**

Thus, the results indicated that the different irrigations at the various IW/CPE ratios, were very crucial in increasing the test weight. Improvement in thousand grain weight in the treatments which were given more number of irrigations might be because of the maintenance of required soil moisture status in the soil at root zone during the different phases of crop growth, especially during crown root initiation, flowering, and dough stages. These results are similar to those reported by Misra et al. (1969), Wilson (1969), Shrotriya et al. (1970), Patel et al. (1971), Kitmmanit (1986) and Prasad (1989).

4.13 YIELD DATA:

4.13.1 Total Produce Per Hectare:

The data pertaining to per hectare total produce at the harvest as affected by the different treatments are presented in Table 26 and graphically shown in Fig. 27.

It will be clear from the data that the total per hectare produce was influenced by the various treatments under the present study.

The total per hectare produce increased with increasing number of irrigations. It was the highest in the treatment with IW/CPE of 1.0 and the lowest in the treatment with IW/CPE of 0.4. The total per hectare produce in the treatments with IW/CPE of 1.0, 0.9 and 0.8 was nearly equal to each other. IW/CPE of 0.7 which was given three irrigations gave more total per hectare produce than did the IW/CPE of 0.6 which also received three irrigations. It might be due to the fact that IW/CPE of 0.7 was given irrigations earlier than was given to IW/CPE of 0.6. In the similar way, IW/CPE of 0.5 recorded more total per hectare produce than did the IW/CPE of 0.4 though both were given two irrigations each.

Table 26 Mean yield of total produce (q ha^{-1}), grain yield (q ha^{-1}), straw yield (q ha^{-1}), grain to straw ratio and harvest index as affected by irrigation treatments

Treatment No.	IW/CPE ratio	Total produce (q ha^{-1})	Grain Yield (q ha^{-1})	Straw Yield (q ha^{-1})	Grain to straw ratio	Harvest index
T_1	1.0	75.90	31.55	44.35	1.406	41.57
T_2	0.9	75.10	31.13	43.97	1.409	41.45
T_3	0.8	74.70	30.93	43.77	1.415	41.40
T_4	0.7	68.50	28.29	40.21	1.421	41.29
T_5	0.6	60.40	24.00	36.40	1.517	39.73
T_6	0.5	45.20	16.80	28.40	1.690	37.16
T_7	0.4	38.22	13.88	24.34	1.754	36.37

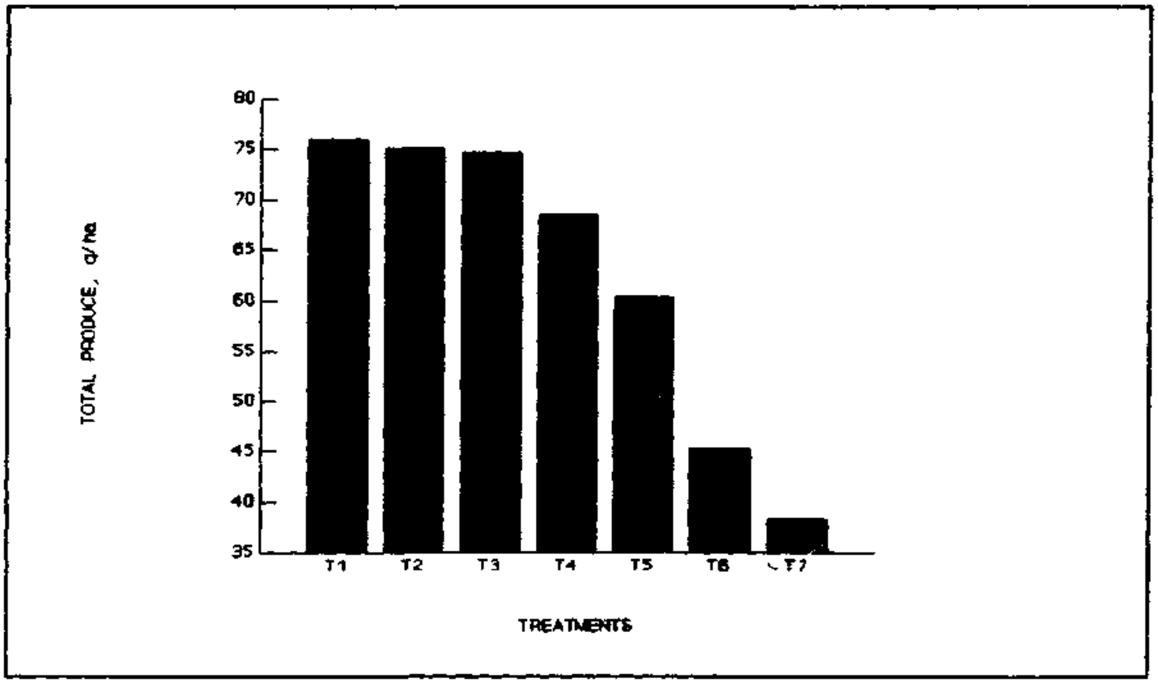

Fig. 27 Total produce (q ha^{-1}) as affected by irrigation treatments

Thus, it is clear that the increasing frequency of irrigation increased the total per hectare produce. Also from the view point of critical growth stages, irrigations applied near crown root initiation and tillering, i.e. at early growth stages were essential. Similarly, irrigations applied near flowering and dough stages were important for higher total produce in wheat. Water stress near these stages reduced the total produce per hectare.

4.13.2 Grain Yield:

The data relating to per hectare mean grain yield in quintal as affected by the different treatment are given in Table 26 and are graphically shown in Fig. 28

The grain yield increased as the frequency of irrigations increased from two to five at the different IW/CPE ratios ranging from 0.4 to 1.0.

The treatment with IW/CPE of 1.0, which received five irrigations, gave the highest grain yield per hectare.

The treatments with IW/CPE of 0.9 and 0.8 which were given four irrigations expressed slightly different grain yields per hectare. The treatment with IW/CPE of 0.7 expressed grain yield higher than the grain yields showed by the treatments with IW/CPE of 0.6, 0.5 and 0.4. The grain yield was drastically reduced in the treatments with IW/CPE of 0.5 and 0.4 which were given only two irrigations. Out of these two, IW/CPE of 0.4 produced the lowest grain yield.

In general, increase in the number of irrigations increased grain yield. The grain yield decreased drastically from IW/CPE of 0.6 onwards and this continued up to IW/CPE of 0.4. It was because they were given irrigations at the time quite away from crown root initiation and tillering stages of crop growth and also away from flowering and dough stages during the crop growth period. Water stress experienced by the crop during these critical stages of crop growth

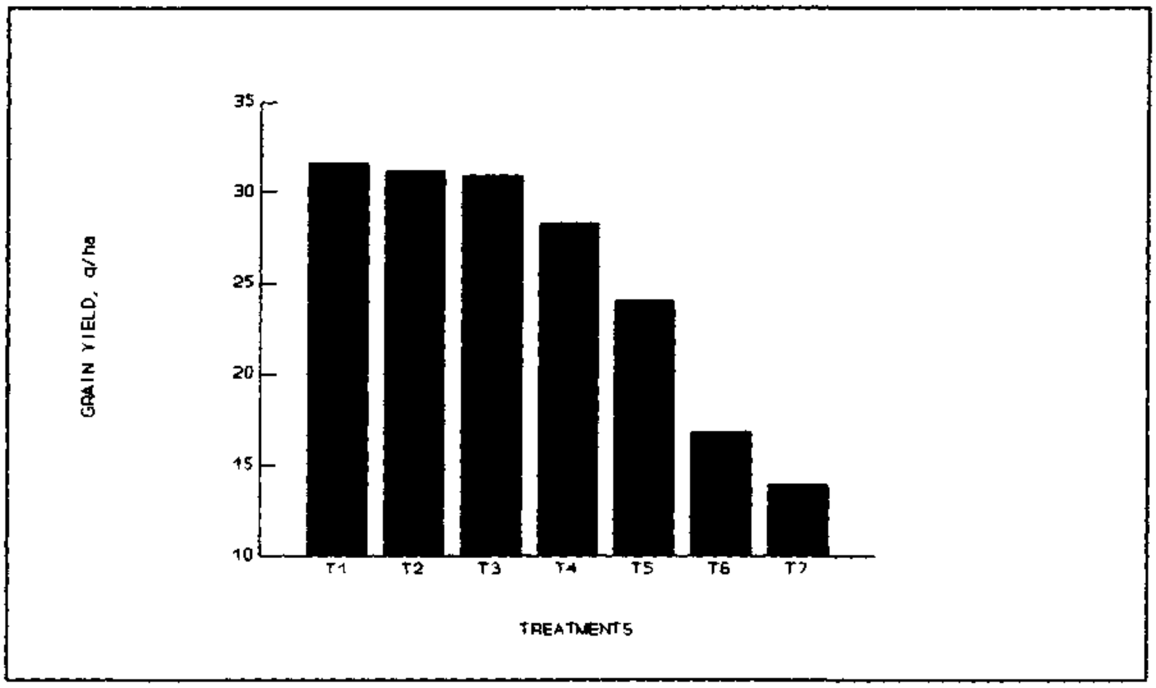

Fig. 28 Grain yield (q ha^{-1}) as affected by irrigation treatments.

drastically reduced the grain yield. These results are similar to those reported by Sekhon (1968), Misra (1969), Patel et al. (1971), Sharma (1987) and Tripathi (1989).

4.13.3 Straw Yield:

The data pertaining to per hectare mean straw yield as affected by the different treatments are presented in Table 26 and graphically shown in Fig. 29

It will be evident from the data that the straw yield was affected by the different treatments as per IW/CPE ratio.

The treatment with IW/CPE of 1.0 which received five irrigations produced the highest amount of straw yield. The treatments with IW/CPE of 0.9 and 0.8 produced the straw yield which was slightly equal to each other and also near to the straw yield of IW/CPE of 1.0. The treatment with IW/CPE of 0.7 produced

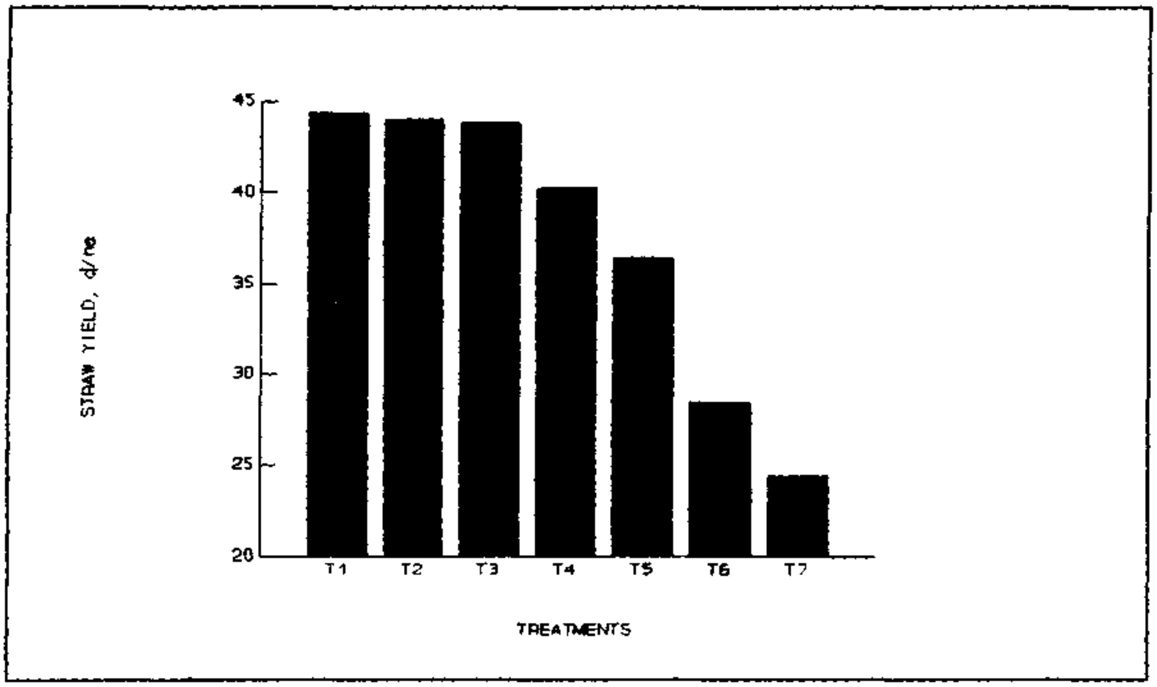

Fig. 29 Straw yield (q ha^{-1}) as affected by irrigation treatments

straw yield which was quite different from that of straw yields of IW/CPE of 1.0, 0.9 and 0.8 but it was more than the straw yield produced in the IW/CPE of 0.6, 0.5 and 0.4. The treatments with IW/CPE of 0.5 and 0.4 where two irrigations were given produced the lower amount of straw yield. The IW/CPE of 0.4 produced the lowest amount of straw yields amongst all the treatments.

Thus, with increase in the number of irrigations as per IW/CPE ratio the production of straw yield was increased. This was because the irrigation given near crown root initiation, tillering, flowering and dough stages was important for the production of higher straw yield. By and large, these results are simlar to those reported by Sekhon et al (1968), Misra et al. (1969), Patel et al. (1971), Mehta et al. (1982) and Malvia (1987).

4.13.4 Grain:Straw Ratio:

Results regarding graın to straw ratıo as affected by the varıous treatments are tabulated in Table 26 and graphically presented in Fig. 30

It will be clear from the data that the grain to straw ratio was affected by the different irrıgatıon treatments.

The treatment with IW/CPE of 0.4 whıch was given only two irrıgations showed the hıghest graın to straw ratıo. The treatment with IW/CPE of 1.0 whıch receıved fıve ırrıgatıons showed the lowest grain to straw ratio. The treatment with IW/CPE of 0.9, 0.8, 0.7, 0.6 and 0.5 were ıntermedıate.

Thus, the results ındicated that the ıncrease ın number of ırrıgatıons basedthe IW/CPE ratıos decreased ratio of graın to straw yıeld.

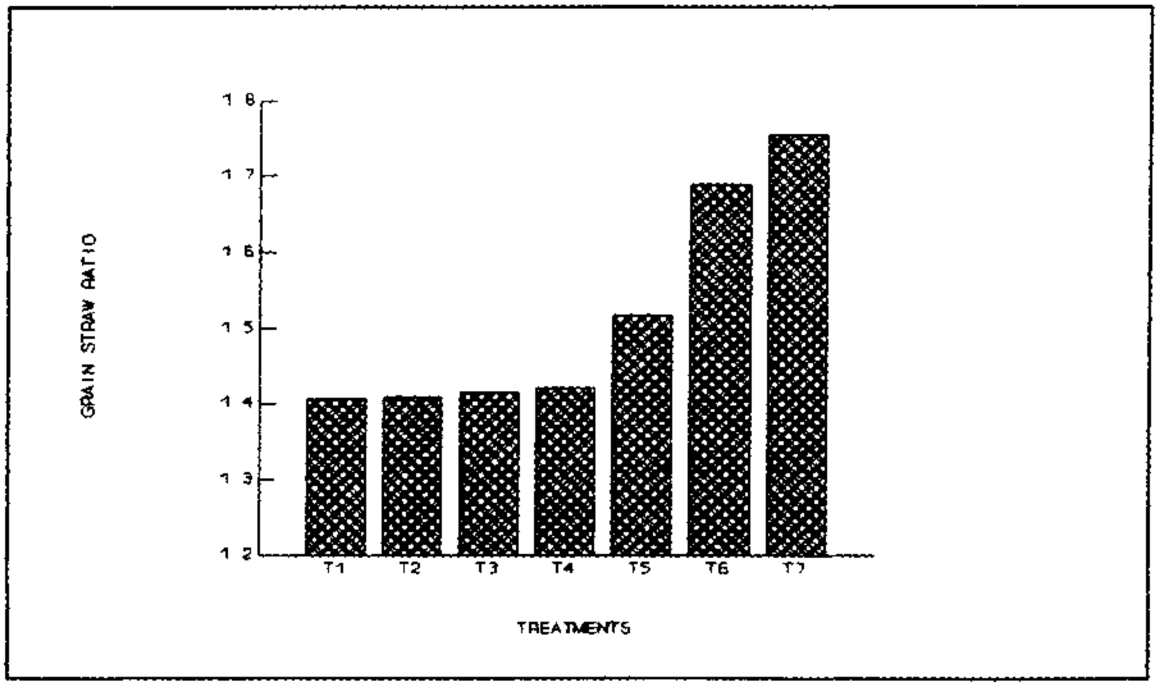

Fig. 30 Graın:Straw ratıo as affected by irrigation treatments

4.14 HARVEST INDEX:

The results regarding harvest index as affected by the different treatments are presented in Table 26 and graphically shown in Fig. 31

It will be evident from the results that the harvest index was affected by the different treatments in the experimentation.

The results showed that IW/CPE of 1.0 which was given five irrigations gave the highest value of harvest index amongst all the treatments. The treatments with IW/CPE of 0.9 and 0.8 showed the value of harvest index quite close to that of IW/CPE of 1.0. The treatment with IW/CPE of 0.7 was better than IW/CPE of 0.6 though both of them were given three irrigations. This might be because the IW/CPE of 0.7 was given irrigations quite earlier than were given to the IW/CPE of 0.6. Due to similar reason, the treatment with IW/CPE of 0.5

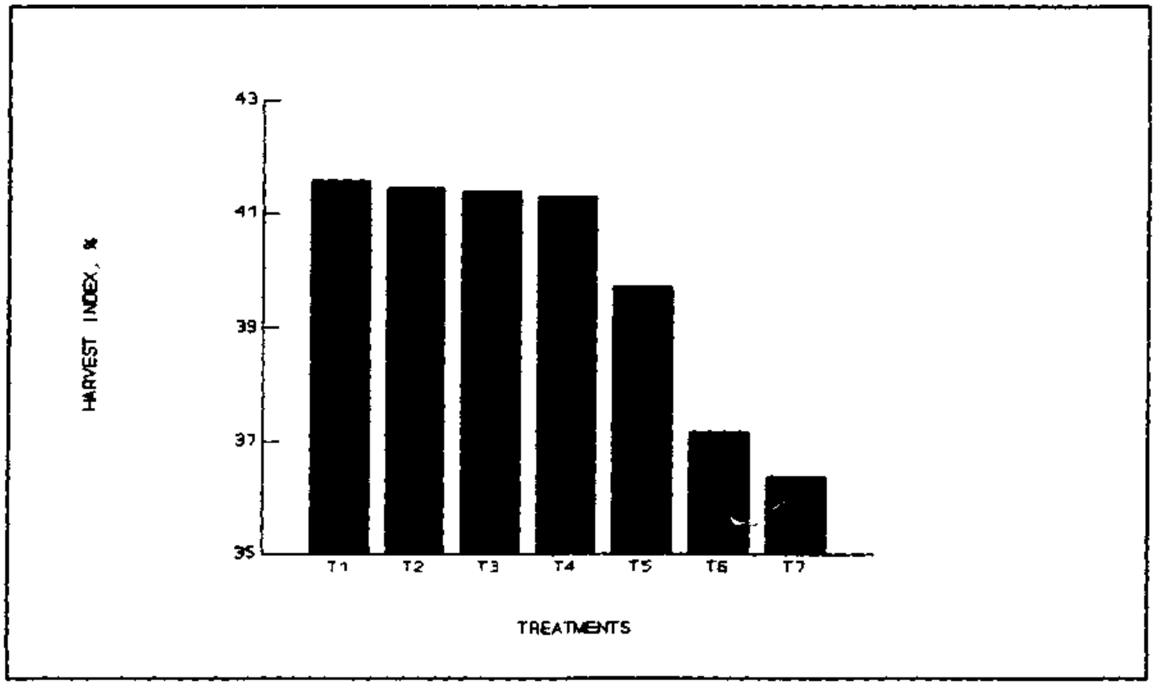

Fig. 31 Harvest Index as affected by irrigation treatments

showed better harvest index than that of IW/CPE of 0.4 though both of them were given two irrigations. The treatment with IW/CPE of 0.4 showed the lowest harvest index among all the treatments. Thus, in general, with increase in the number of irrigations, the harvest index also increased.

4.15 RELATIONSHIP BETWEEN EVAPOTRANSPIRATION (ET) AND GRAIN YIELD:

The data regarding relationship between evapotranspiration and grain yield is presented in Table 27 and graphically shown in Fig. 32

The data of evapotranspiration and grain yield was fitted in equations. The equation of parabola gave the best fit.

$$Y = a + bx + cx^2$$

The actual equation is as follows:

$$Y = -61.246 + 0.4577x - 0.00056x^2$$

Where,

a,b,c = Constants

Y = Grain Yield (q ha^{-1})

x = Evapotranspiration (mm)

From the Fig. 32 it will be observed that with the increase in evapotranspiration, the grain yield also increased. Also the predicted and actual values of grain yield were close together.

Table 27 Relationship between evapotranspiration (mm) and grain yield (q ha^{-1}

Treat-ment	T_1	T_2	T_3	T_4	T_5	T_6	T_7
IW/CPE ratio	1.0	0.9	0.8	0.7	0.6	0.5	0.4
Yield (actual)	31.55	31.13	30.93	28.29	24.00	16.80	13.88
Yield (predicted)	31.36	31.51	31.09	27.17	24.93	16.02	14.02
ET	432.60	386.30	372.50	316.20	296.20	238.90	231.10

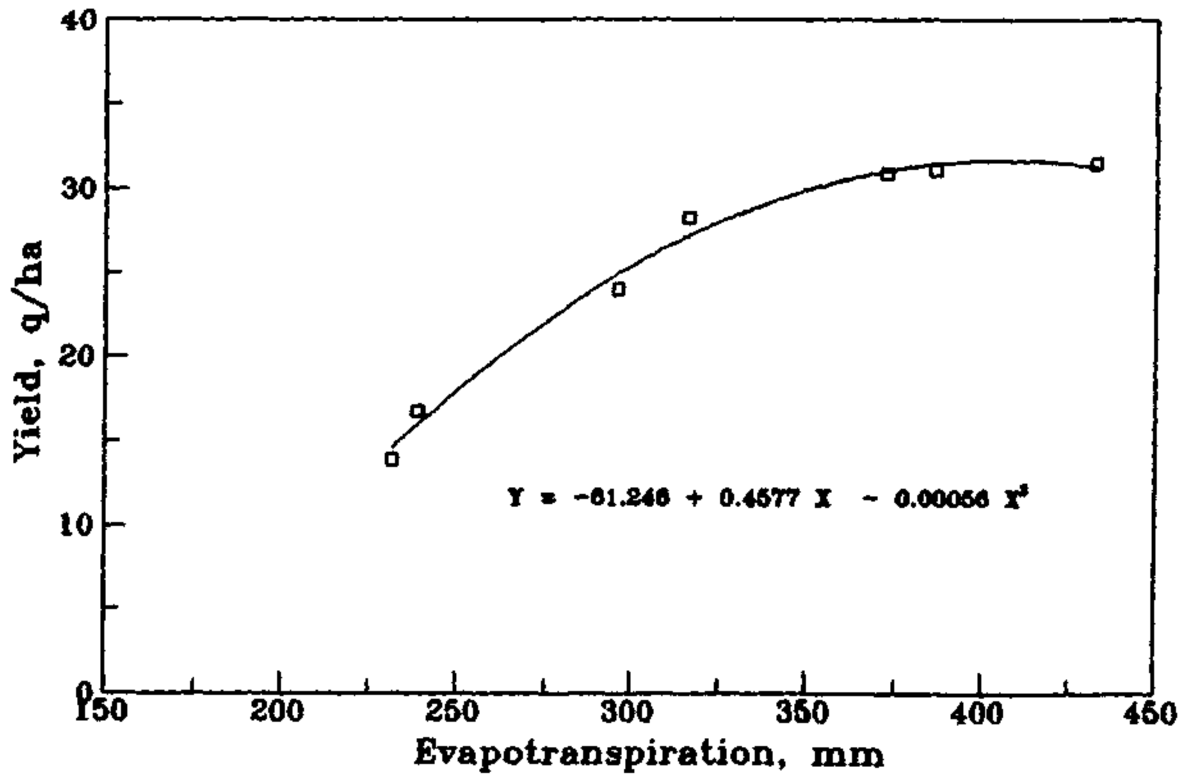

Fig. 32 Relationship between ET and grain yield (qtl ha^{-1})

This might be because of the fact that with increase in the number of irrigation, the soil moisture increased and with increase in soil moisture status of the soil the evapotranspiration of crop increased. The increase in evapotranspiration might have caused more CO_2 assimilation thus resulted in greater yield. The curve of observed values followed closely the curve of predicted values, thus it was inferred that the equation of parabola had the best fit in the data of evapotranspiration and grain yield.

4.16 WATER USE EFFICIENCY (WUE):

Water use efficiency as affected by the different irrigation treatments are presented in Table 28 and Fig. 33

It will be evident from the table that with increase in the number of irrigations, water use efficiency decreased, while with decrease in the number of irrigation, the water use efficiency increased up to certain extent then it went on decreasing.

The treatment with IW/CPE of 0.7 which received three irrigations produced maximum total dry matter per mm of consumptive use thereby giving the highest water use efficiency. The treatment with IW/CPE of 0.4 which received two irrigations produced the lowest total dry matter per .mm of consumptive use and gave the lowest water use efficiency. The treatment with IW/CPE of 1.0 which received five irrigations showed the water use efficiency lower than that of IW/CPE of 0.9 and 0.8 which received four irrigations. The treatment with IW/CPE of 0.6 which received three irrigations showed water use efficiency more than that of the treatments with IW/CPE of 1.0 and 0.9.

Table 28 Water use efficiency (WUE) i.e. total dry matter and grain yield (kg) per mm of consumptive use (CU) of water

Treatment No.	T_1	T_2	T_3	T_4	T_5	T_6	T_7
IW/CPE ratio	1.0	0.9	0.8	0.7	0.6	0.5	0.4
Irrigations	5.0	4.0	4.0	3.0	3.0	2.0	2.0
Grain yield	31.55	31.13	30.93	28.29	24.00	16.80	13.88
Consumptive use	432.60	386.90	372.50	316.20	296.20	238.90	231.10
WUE (kg/mm of cu)	7.293	8.059	8.303	8.947	8.103	7.032	6.006
Total dry matter	75.90	75.10	74.70	68.50	60.40	45.20	38.22
Consumptive use	432.60	386.90	372.50	316.20	296.20	238.90	231.10
WUE (kg/mm of cu)	17.55	19.42	20.05	21.66	20.39	18.92	16.52
Predicted values	17.6692	19.4153	19.8835	21.1719	21.1649	18.0777	17.1276

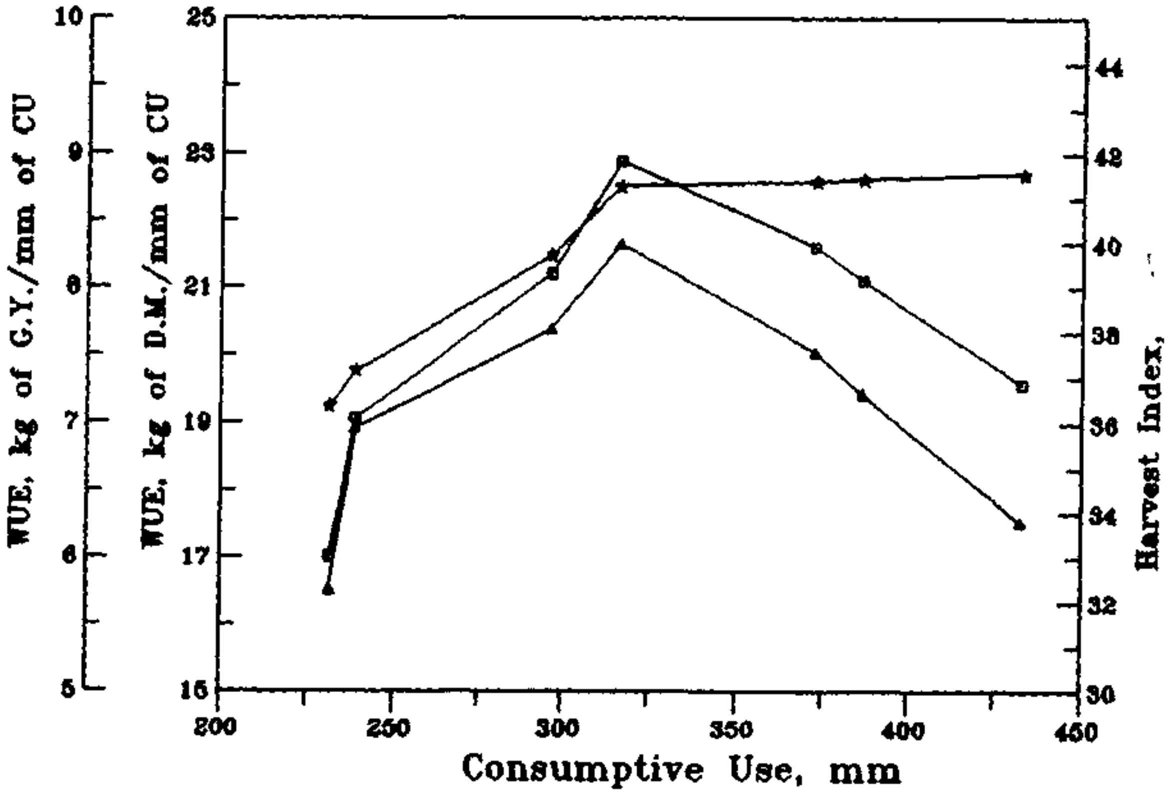

Fig. 33 Water use efficiency and harvest index as affected by irrigation treatments

Increase or decrease in the number of irrigations beyond three, produced less total dry matter per mm of consumptive use. Irrigations delivered at the 26th, 56th and 81st days after sowing were observed to be critical in respect of irrigation for producing maximum total dry matter per unit of water consumed.

However, the experimental results obtained by Mujumdar and Mandal (1984) suggest that wheat crop be irrigated at an IW/CPE ratio of 0.9 to harvest and optimum yield with an optimum water use efficiency. Malvia et al. (1986) found that the water use efficiency was the highest at IW/CPE of 0.8. This might be because of the differences between depths of irrigation given during these experiments. In general the higher consumptive use resulted in lower water use efficiency. These results are similar to those reported by Reddy (1982), Ashok Kumar (1986) and Tripathi (1989).

The water use efficiency of wheat crop can be predicted by using the second order hyperbola (Fig. 33):

$$Y = a + \frac{b}{x} + \frac{c}{x^2}$$

The equation obtained is given below:

$$Y = (-19.69643) + \frac{(24970.52573)}{x} + \frac{(-3.8095 \times 10^6)}{x^2}$$

where,

Y = Consumptive use in mm

X = Water use efficiency

The relationship between actual and predicted water use efficiency is presented in Fig. 34

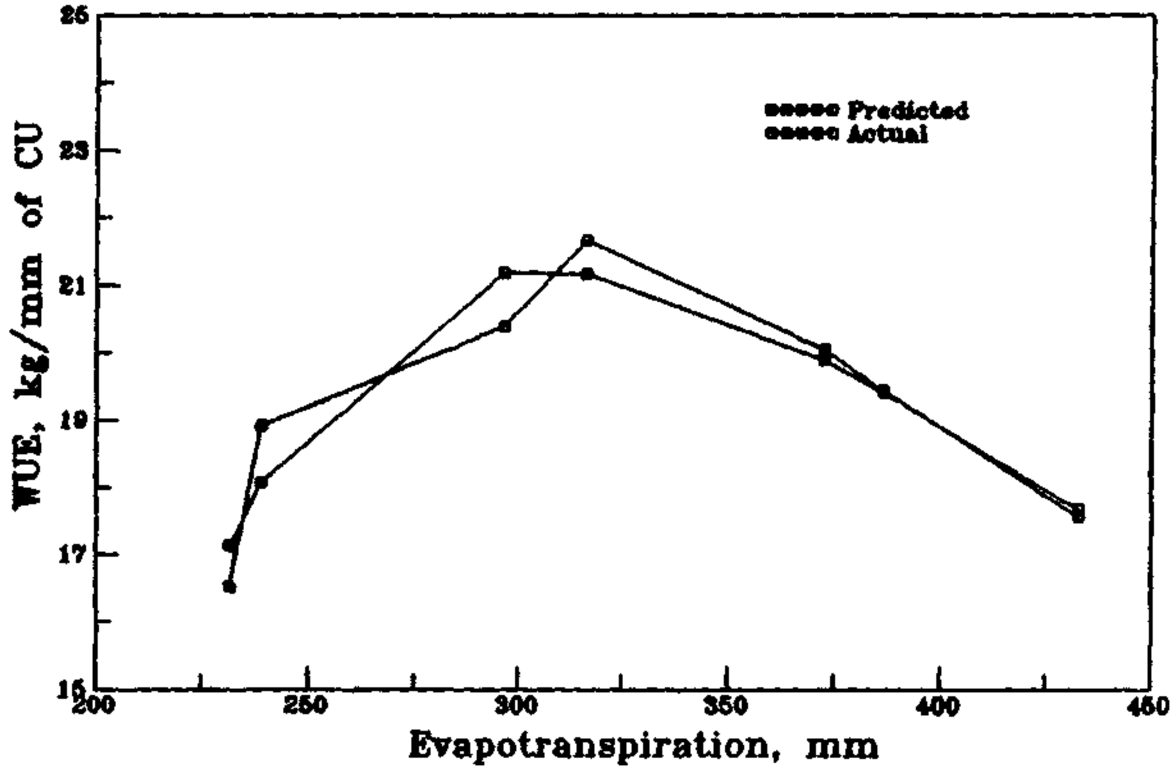

Fig. 34 Relationship between water use efficiency and ET

4.17 CROP COEFFICIENT (Kc) OF WHEAT CROP AT DIFFERENT GROWTH STAGES FOR PUNE:

The data regarding crop coefficients (Kc) at the different growth stages of wheat crop are presented in Table 29 and graphically shown in Fig. 35

Crown root initiation stage:

The treatment with IW/CPE of 1.0 showed the highest Kc value (0.928) while the remaining treatments with IW/CPE of 0.9 to 0.4 showed the same Kc value (0.896) at crown root initiation stage.

This might because the crown root initiation stage occurred on the 20th day after sowing and up to this stage only IW/CPE of 1.0 received one irrigation due to which the ET was more giving the highest Kc value.

Table 29 Crop coefficients of wheat crop at physiological growth stages for Pune

Treatment No.	T_1	T_2	T_3	T_4	T_5	T_6	T_7
IW/CPE ratio	1.0	0.9	0.8	0.7	0.6	0.5	0.4
Irrigations	5.0	4.0	4.0	3.0	3.0	2.0	2.0
Crop growth stages			Crop coefficient				
CRI	0.928	0.896	0.896	0.896	0.896	0.896	0.896
Tillering	1.225	1.202	1.134	1.062	0.869	0.763	0.763
Jointing	1.572	1.479	1.202	1.173	1.148	0.774	0.439
Flowering	1.865	1.770	1.642	1.389	1.111	0.941	0.829
Milk	1.580	1.563	1.517	1.320	1.068	0.899	0.849
Maturity	0.990	0.848	0.974	0.658	0.835	0.642	0.833

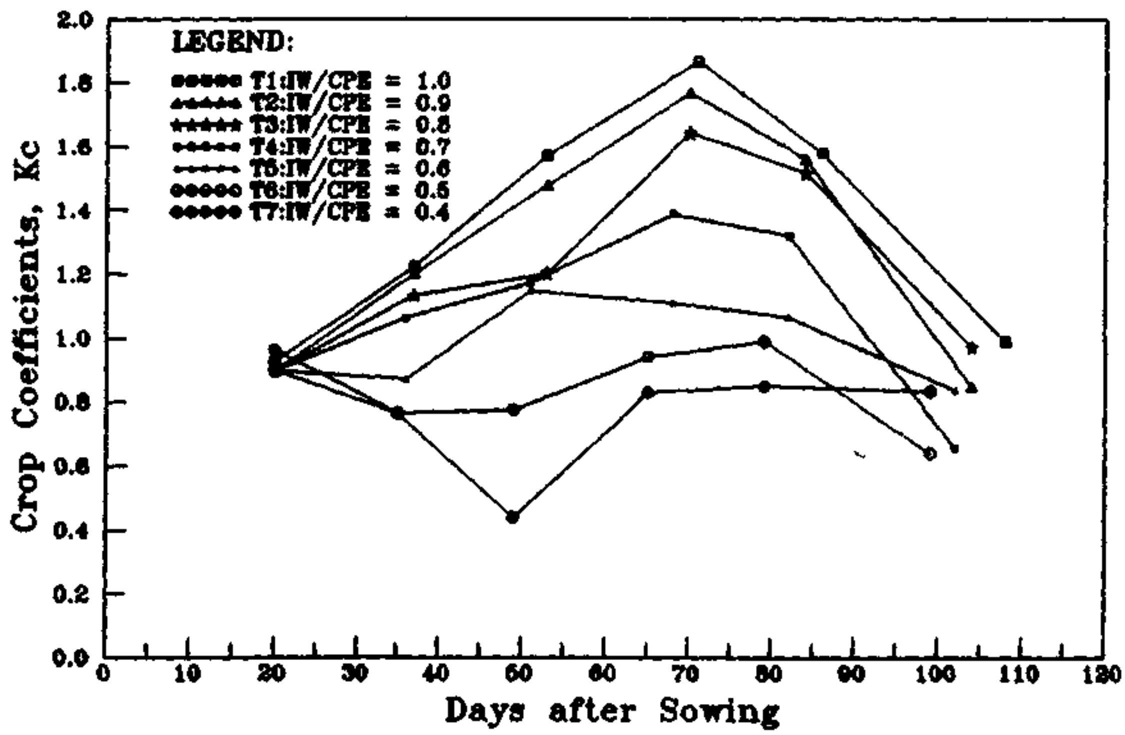

Fig. 35 Crop coeffcients of wheat crop for irrigation treatments

Tillering stage:

The treatment with IW/CPE of 1.0 showed the highest Kc (1.225) value while the treatments with IW/CPE of 0.5 and 0.4 showed the lowest Kc (0.763) value at the tillering stage. This was because the tillering stage occurred at 37 days after sowing in the treatments with IW/CPE of 1.0, 0.9 and 0.8, at 36 days in the treatments with IW/CPE of 0.7 and 0.6 and at 35 days in the treatment with IW/CPE of 0.5 and 0.4. Up to this stage the treatments with IW/CPE of 1.0. 0.9, 0.8, 0.7 and 0.6 had received one irrigation. The treatment with IW/CPE of 1.0 received first irrigation earlier than the rest of the treatments. Due to this, the ET was more and Kc value was the highest.

Jointing stage:

At the jointing stage, the treatment with IW/CPE of 0.4 showed the lowest Kc (0.439) value, while the treatment with IW/CPE of 1.0 showed the highest Kc (1.572) value.

This might be because the jointing stage occurred at the 53^{rd} day after sowing in the treatments with IW/CPE of 1.0, 0.9 and 0.8; at 51^{st} days after sowing in the treatments with IW/CPE of 0.7 and 0.6 and at the 49^{th} day after sowing in the treatments with IW/CPE of 0.5 and 0.4. Up to this stage, the treatment with IW/CPE of 1.0, 0.9 and 0.8 received two irrigations and IW/CPE of 0.7, 0.6, 0.5 and 0.4 received one irrigation. Though the treatment with IW/CPE of 1.0, 0.9 and 0.8 received two irrigations, IW/CPE of 1.0 showed the highest Kc value because it received both the irrigations quite earlier resulting in higher ET.

Flowering stage:

The flowering stage occurred on the 71st day after sowing in IW/CPE of 1.0, at the 78th day in IW/CPE of 0.9 and 0.8 on the 68th day in IW/CPE of 0.7 and 0. and on the 65th in IW/CPE of 0.5 and 0.4. Up to this stage, the treatments with IW/CPE of 1.0 and 0.9 received three irrigations, the treatments with IW/CPE of 0.8, 0.7 and 0.6 received two irrigation and the treatments with IW/CPE of 0.5 and 0.4 received only one irrigation. Hence, the treatment with IW/CPE of 0.4 showed the lowest Kc (0.829) value while the treatment with IW/CPE of 1.0 showed the highest Kc (1.824) value.

Though the treatments with IW/CPE of 1.0 and 0.9 received three irrigations, the IW/CPE of 1.0 showed the highest Kc value because it received all the three irrigations quite earlier resulting in more ET. Also the treatment with IW/CPE of 0.5 and 0.4 received one irrigation. However, IW/CPE of 0.4 showed the lowest Kc value because it received irrigation later than did the IW/CPE of 0.5 and its ET was less, ultimately giving the lowest Kc value.

Milk stage:

At milk stage, the treatment with IW/CPE of 1.0 showed the highest Kc(1.580) value, while the treatment with IW/CPE of 0.4 showed the lowest Kc (0.849) value.

This might be because the milk stage occurredthe on 86th day after sowing in the treatment with IW/CPE of 1.0, on the 84th day in the treatments with IW/CPE of 0.9 and 0.8, on the 82nd day in the treatments with IW/CPE of 0.7 and 0.6 and on the 79th day in the treatments with IW/CPE of 0.5 and 0.4. Up to this stage, IW/CPE of 1.0 received four irrigations, which were earlier than the rest of the treatments. Hence, the ET was more giving highest Kc. IW/CPE of 0.4

received only one irrigation till this stage due to which the ET was low and Kc value was the lowest.

Physiological maturity:

At physiological maturity, the treatment with IW/CPE of 1.0 showed the highest Kc (0.990)value because it received five irrigations, due to which its ET was the highest.

The treatment with IW/CPE of 0.8 showed higher Kc (0.974) value than did Kc (0.848) value IW/CPE of 0.9 though both received four irrigations. The treatment with IW/CPE of 0.6 showed higher Kc (0.835) value than did Kc (0.658) value of IW/CPE of 0.7 though both received three irrigations. The treatment with IW/CPE of 0.4 showed higher Kc (0.833) value than did Kc (0.692) value of IW/CPE of 0.5 though both received two irrigations.

This might be because the air temperature was higher from the 93rd days onwards along with windy conditions. As the treatments with IW/CPE of 0.8, 0.6 and 0.4 received the irrigations just before this stage, naturally the evapotranspiration was more than that of IW/CPE of 0.9, 0.7 and 0.5 resulting in higher Kc values.

The crop coefficient (Kc) values were less than unity in the beginning and during the late growth stages but exceeded unity at the maximum tillering to milk stage. The results are in line with those of Singh and Haudal (1988).

4.18 DECIDE IRRIGATION SCHEDULING OF WHEAT CROP FOR OPTIMUM YIELD:

The treatment with IW/CPE of 1.0 was given five irrigations and produced the highest grain yield (31.55 q ha^{-1}). This indicates that when water for five irrigations is available, then the irrigations given on the 19th, 39th, 61st, 78th and 94th days after sowing, was beneficial.

The treatment with IW/CPE of 0.9 and 0.8 was given four irrigations each. However, IW/CPE of 0.9 produced more grain yield. This indicates when water for four irrigations was available then the irrigation given on the 21st, 46th, 69th and 87th days after sowing, was beneficial.

The treatment with IW/CPE of 0.7 and 0.6 was given three irrigation each. However, IW/CPE of 0.7 produced more grain yield. Also it gave the highest water use efficiency. This indicates that when water for three irrigations was available then the irrigation be given on the 26th, 56th and 81st days after sowing, was useful.

The treatment with IW/CPE of 0.5 and 0.4 was given two irrigations. However, IW/CPE of 0.5 produced more grain yield. This indicates that when water for two irrigations was available then the irrigations given on the 39th and 78th days after sowing.

The treatments with IW/CPE of 0.9 and 0.8 were given four irrigation but IW/CPE of 0.9 produced more grain yield. The treatment with IW/CPE of 0.7 and 0.6 were given three irrigations but IW/CPE of 0.7 was produced more grain yield. The treatments with IW/CPE of 0.5 and 0.4 were given two irrigations but IW/CPE of 0.5 produced more grain yield. The treatment with IW/CPE of 1.0 was given irrigations and produced the highest grain yield. This might be because the treatments with IW/CPE of 1.0, 0.9, 0.7 and 0.5 received the irrigations earlier and which approximately matched with the physiological stages of the crop growth resulting in higher grain yield.

5. SUMMARY AND CONCLUSIONS

5. SUMMARY AND CONCLUSIONS

5.1 Summary:

Field investigation entitled, "to study the evapotranspiration of wheat crop in varying soil moisture condition" was conducted in "E" Division of the Agronomy Farm of the College of Agriculture, Pune in the post monsoon season (rabi) of the year 1989-90. Irrigations were given as per IW/CPE ratio with the following objectives:

i. To study evapotranspiration of wheat crop at different soil moisture depletion levels;

ii. To study water use efficiency of wheat crop at different soil moisture depletion levels;

iii. To work out crop coefficients of wheat crop at different growth stages for Pune; and

iv. To decide irrigation scheduling of wheat crop for optimum yield.

The experiment was conducted on the soil with clay loam texture having good water holding capacity. The experiment had seven treatments and was replicated two times. Thus, the total plots were fourteen. The gross plot size was 6 x 3.6 m^2 and the net plot size was 5.4 x 2.7 m^2.

The treatment with IW/CPE of 1.0 was given five irrigations respectively on the on 19th, 39th, 61st, 78th and 94th days, after sowing. The treatment with IW/CPE of 0.9 was given four irrigations respectively on 21st, 46th, 69th and 87th days, after sowing. The treatment with IW/CPE of 0.8 was given four irrigations respectively on the 24th, 52nd 73rd and 93rd days, after sowing. The treatment with IW/CPE of 0.7 was given three irrigations respectively on the 26th, 56th, and 81st days, after sowing. The treatment with IW/CPE of 0.6 was given three irrigations respectively on the 31^{st}, 66^{th} and 93^{rd} days, after sowing. The treatment with IW/CPE of 0.5 was given two irrigations on the 39^{th} and 78^{th} days, respectively after sowing. The treatment with IW/CPE of 0.4 also was given two irrigations respectively on the 52^{nd} and 94^{th} days, after sowing. Thus, the set of seven treatments was given irrigations 2 to 5 in the present experiment.

The season during the crop growth period was normal. There was no disease or pest incidence observed on the crop. The precautionary measures were adopted during the season.

In the present investigation the growth stages viz. crown root initiation, tillering, jointing, flowering, milk and maturity were observed respectively on 20^{th}, 35^{th} to 37^{th}, 49^{th} to 53^{th}, 65^{th} to 71^{st}, 79^{th} to 86^{th} and 99^{th} to 108^{th} day, from the date of sowing. For finding out the crop coefficients and to study the growth and development characters, yield contributing characters and yield observations were recorded at different growth stages of the plant.

Uniform fertilizer doses were provided for all the treatments, i.e. 50 kg N + 50 kg P_2O_5 + 50 kg K_2O per hectare. Suphala 15:15:15 was used as the source. The fertilizer dose was broadcasted uniformly before sowing and mixed thoroughly into the soil.

Soil moisture was measured with the help of Neutron probe from 15 to 90 cm at an interval of 15 cm depth.

Leaf area was measured with the help of leaf area meter. The growth characters such as plant height, number of tillers, number of functional leaves, leaf area and dry matter were recorded at the different stages of crop growth. The yield contributing and yield characters such as length of earhead, number of functional spikelets, number of grains per earhead, grain weight per earhead and thousand grain weight were recorded at harvest. The meteorological data required for estimation of potential evapotranspiration and vapour pressure deficit was collected from Agricultural Meteorological Observatory located at the College of Agricultural Farm, Pune. Some of the important findings emerging from this investigation are summarized below.

5.1.1 Effect of Irrigation on Evapotranspiration:

Evapotranspiration increased with increase in the number of irrigations as per the IW/CPE ratio.

The treatment with IW/CPE of 1.0 which was given five irrigations showed the highest evapotranspiration while the treatment with IW/CPE of 0.4 which was given only two irrigations showed the lowest evapotranspiration. The results of other treatments were in between the above two treatments.

Evapotranspiration was more in between the flowering and grain formation stage during the crop growth period.

5.1.2 Effect of Irrigation on Growth Characters:

Height of the crop was, by and large, directly related to the number of irrigations received by the crop. Amongst the treatments, IW/CPE of 1.0 showed the maximum height which was given five irrigations and IW/CPE of 0.4 showed the minimum height which was given two irrigations. The other treatments were in between the above two treatments. As per the critical stages, irrigations received near about jointing stage (at boot stage) observed to be critical because the treatment with IW/CPE of 1.0, 0.9 and 0.8 received the irrigation about the time of boot stage and there was not much difference between them in respect of height.

The leaves continued to function and remained green for a longer period when the crop had adequate moisture. The crop with inadequate moisture dried earlier. Leaf area and leaf area index increased in proportion to increase in the number of irrigations.

Number of tillers per plant was directly related to the number of irrigations received by the crop. It was noticed that the number of tillers per plant increased considerably when irrigations were received by the crop at the early stage around 19 to 21 days after sowing; followed by subsequent irrigations near about jointing, flowering and dough stages of crop growth.

Dry matter per plant was also observed to increase with the increase in the number of irrigations received by the crop. For more dry matter production, higher soil moisture was required to be maintained during the vegetative growth period. Amongst the crops growth stages, the irrigation received near about the crown root initiation and tillering stage was observed to be critical in this respect. Thus, all the growth attributes were considerably improved when irrigations were received near by critical stages. These growth attributes were affected adversely when only two irrigations were received as in the case of the treatment with IW/CPE of 0.4.

The number of days required for maturity was directly related to the number of irrigations received by the crop. As the number of irrigations decreased the maturity was enhanced.

5.1.3 Effect of Irrigation on Yield Contributing Characters:

Length of earhead was substantially affected by the frequency of irrigations. More number of irrigations gave more length of earhead.

Spikelet and grain number per earhead increased with the increase in the number of irrigations. Irrigation near about jointing (at boot stage) was observed to be critical in this respect.

Grain weight per earhead was observed to be increased, when irrigation was received near by crown root initiation and late tillering stage. With stress near to early growth period and flowering stage. The grain weight per earhead was adversely affected .

The studies on development of individual grain as indicated by thousand grain weight, revealed that irrigation received by crown root initiation, flowering and dough stages was very important.

5.1.4 Effect of Irrigation on Yield:

Total dry matter produce, grain and straw yield was observed, by and large, to be increased as the frequency of irrigation increased. Irrigation received near to the crown root initiation, late tillering, flowering and dough stages was observed to be critical. Stress applied near to these stages reduced the grain yield.

Grain:Straw ratio, in general was observed to be decreasing with increase in irrigation number as per IW/CPE ratio.

Harvest index results showed that with increase in the number of irrigations the harvest index was also increased.

5.2 EFFECT OF IRRIGATION ON WATER USE EFFICIENCY (WUE):

The treatment with IW/CPE of 1.0 which received five irrigations showed the WUE lower than that of the treatments with IW/CPE of 0.9 and 0.8 which received four irrigations. The treatment with IW/CPE of 0.6 which received three irrigations showed WUE more than that of the treatments with IW/CPE of 1.0 and 0.9.

The treatment with IW/CPE of 0.7 which was given three irrigations showed the highest water use efficiency. Increase or decrease in the number of irrigations beyond three produced less total dry matter per unit of water use.

5.3 EFFECT OF IRRIGATION ON CROP COEFFICIENT (Kc):

Crop coefficient values at the different stages increased with the number of irrigations as per IW/CPE ratio. Crop coefficient values are useful in scheduling irrigation to wheat crop at various growth stages.

Crop coefficient values for the treatment with IW/CPE of 0.7 were 0.896, 1.062, 1.173, 1.389, 1.320 and 0.658 at the crown root initiation, tillering, jointing, flowering milk and physiological maturity, respectively.

5.4 PRACTICAL SIGNIFICANCE:

Under the conditions of limited water supply, when water supply is just sufficient for two irrigations only, the irrigations given as per IW/CPE of 0.5, i.e. on the 39th and 78th days after sowing proved to be better than IW/CPE of 0.4 in which the irrigations were given on the 52nd and 93rd day after sowing.

When there was availability of only three irrigations, IW/CPE of 0.7 which was given irrigations on the 26th, 56th and 81st days after sowing proved to be better than IW/CPE of 0.6 in which irrigations were given on the 31st, 66th and 93rd days after sowing. Four irrigations were given according to IW/CPE of 0.9 on the 21st, 46th, 69th and 87th day after sowing proved to be better than those given according to IW/CPE of 0.8 on the 24th, 52nd, 73rd and 93rd day after sowing.

Though the treatment with IW/CPE of 1.0 was given five irrigations on the 19th, 61st, 78th and 94th day after sowing, it showed lower water use efficiency. However, it showed higher potential yield.

5.5 CONCLUSION:

The results of the study conclude that the evapotranspiration of wheat crop increases with increase in the number of irrigations. The growth characters such as plant height, number of tillers, number of functional leaves, leaf area and dry matter were observed to be by and large proportionate with increase in irrigation number. Yield attributes such as length of earhead, number of spikelet, number of grains per earhead, grain weight per earhead, thousand grain weight were also increased as the number of irrigation increased. Increase in ET caused more dry matter production and thus yield. But increase in the number of irrigations beyond certain limit may not be profitable when the cost of irrigations is taken into account. In the present study, the treatment with IW/CPE of 0.7 was found to be the best in respect of water use efficiency.

The irrigation given according to the treatments with IW/CPE of 0.9, 0.8, and 0.7 nearly synchronized with the critical crop growth stages, while the treatments with IW/CPE of 0.6, 0.5 and 0.4 were out of tune. However, if the concept of irrigation at critical growth stages was followed, the crops might be irrigated excessively without atmospheric demand. By using the concept of irrigation as per IW/CPE ratio, crop can be irrigated at the appropriate soil moisture depletion level. Thus, scheduling of irrigation by using the IW/CPE ratio is acceptable over irrigation at the critical growth stages.

5.6 RECOMMENDATIONS:

1. Irrigations given on the 26^{th}, 56^{th} and 81^{st} day after sowing had the highest water use efficiency, i.e. 21.66 kg per mm of consumptive use. Therefore, irrigations at IW/CPE of 0.7 is recommended for further study.

2. For the study on potential yield, the treatments with IW/CPE of 1.4, 1.2, 1.0 and 0.8 should be considered.
3. For the study of water use efficiency, the treatments with IW/CPE of 0.8, 0.7 and 0.6 should be considered.

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APPENDIX

1. Introduction

The formula, designed in 1948 by Penman for the estimation of evaporation from a free water surface and of potential evapotranspiration from a vegetative cover, has been widely used throughout the world for the last 30 years with generally satisfactory results. The method has been widely applied in FAO activities requiring the knowledge of potential evapotranspiration.

One of the main difficulties for the user is not so much the rather large number of climatic parameters involved in the formula, as the computation itself, particularly if these parameters are expressed in units different from those originally used by Penman. When using the formula it is essential either to keep to the units originally used by Penman or to adopt the appropriate conversion coefficients.

In view of these difficulties a first version of this note was prepared in 1972. It is felt that, in spite of the progress made since then in the area of pocket and desk minicomputers, it is still useful to have available a simple method for field calculations of the Penman formula

2 Coefficients used in the formula

The original formula was designed for the environmental conditions of southern England Some small modifications to the original formula have been introduced to take into account experience gathered in FAO with the use of the formula around the world

2.1 The coefficients a and b used in the Angstrom formula for the estimation of the total radiation from the data of sunshine duration are often subject to discussion. Many tests made within FAO projects have shown that three sets of coefficients allow good results to be obtained in the various zones of the world These sets of coefficients are

a		b	
0.18	+	0.55	for the cold and temperate zones
0.25	+	0.45	for dry tropical zones
0.29	+	0.42	for humid tropical zones

The map attached, based on Trewartha (1957) shows these different zones. The zones shown on the map have only an indicative value.

2.2 The values of radiation at the limit of the atmosphere have been calculated on the basis of a solar constant of 2.00 $cal.cm^{-2}.min^{-1}$.

2.3 Estimations of evapotranspiration made in very dry environments, characterized by annual average minimum temperatures above 5°C and differences between monthly average maximum and minimum temperatures of more than 12°C, show an underestimation of potential evapotranspiration due in most cases to the advection of dry air.

In order to remedy this situation, verified in extreme climates, the coefficient affecting the wind speed at 2 m above the ground (U) has been modified in the following way:

Monthly mean minimum temperature	Difference between mean monthly maximum and minimum temperatures	Coefficient of U
-	$\bar{T}_M - \bar{T}m \leq 12^oC$	0.54
> 5°C	$12^o < \bar{T}_M - \bar{T}m \leq 13^oC$	0.61
> 5°C	$13^o < \bar{T}_M - \bar{T}m \leq 14^oC$	0.68
> 5°C	$14^o < \bar{T}_M - \bar{T}m \leq 15^oC$	0.75
> 5°C	$15^o < \bar{T}_M - \bar{T}m \leq 16^oC$	0.82
> 5°C	$16^o < \bar{T}_M - \bar{T}m$	0.89

The tables VIII and IX have been divided into six to accommodate the various coefficients for the calculation of evapotranspiration and evaporati

2.4 Other coefficients have also been proposed for the estimation of the effective radiation. Results of research in this field, however, are not very conclusive. For this reason the coefficients first proposed by Brunt have been maintained.

3. Description of the working sheet

Realizing these difficulties and the importance of trying to simplify the calculations involved in the Penman formula, with particular reference to field projects where elaborate calculating facilities are not often readily available, two simple working sheets have been prepared, allowing the calculations to be made step by step, with the help of tables valid for altitudes between 50°N and 50°S.

A copy of the two working sheets, one for the computation of potential evapotranspiration and the other for the computation of the evaporation of a free water surface, are presented.

The two sheets differ from one another in the figure adopted for the albedo,1/ this being 25% for the vegetative cover and only 5% for the water surface. Another difference appears in the so-called aerodynamic term, where the constant factor associated with the wind speed is 1.00 in the case of the vegetation, to allow for greater roughness of the evaporating surface, and 0.50 in the case of the evaporation of water.

The two formulae for the computation of potential evapotranspiration and evaporation from a free surface of water now read as follows:

1/ The albedo expresses the percentage of short-wave incoming radiation reflected by the soil cover or the water surface.

TABLE I - R_A

Solar radiation on a horizontal surface at the limit of the atmosphere expressed as mm of evaporable water and for a solar constant = 2.00 $cal.cm^2.min^{-1}$

Northern Hemisphere

Lat N	J	F	M	A	M	J	J	A	S	O	N	D
50°	3.81	6.10	9.41	12.71	15.76	17.12	16.44	14.07	10.85	7.37	4.49	3.22
48°	4.33	6.60	9.81	13.02	15.88	17.15	16.50	14.29	11.19	7.81	4.99	3.72
46°	4.85	7.10	10.21	13.32	16.00	17.19	16.55	14.51	11.53	8.25	5.49	4.27
44°	5.30	7.60	10.61	13.65	16.12	17.23	16.60	14.73	11.87	8.69	6.00	4.70
42°	5.86	8.05	11.00	13.99	16.24	17.26	16.65	14.95	12.20	9.13	6.51	5.19
40°	6.44	8.56	11.40	14.32	16.36	17.29	16.70	15.17	12.54	9.58	7.03	5.68
38°	6.91	8.98	11.75	14.50	16.39	17.22	16.72	15.27	12.81	9.98	7.52	6.10
36°	7.38	9.39	12.10	14.67	16.43	17.16	16.73	15.37	13.08	10.59	8.00	6.62
34°	7.85	9.82	12.44	14.84	16.46	17.09	16.75	15.48	13.35	10.79	8.50	7.18
32°	8.32	10.24	12.77	15.00	16.50	17.02	16.76	15.58	13.63	11.20	8.99	7.76
30°	8.81	10.68	13.14	15.17	16.53	16.95	16.78	15.68	13.90	11.61	9.49	8.31
28°	9.29	11.09	13.39	15.26	16.48	16.83	16.68	15.71	14.08	11.95	9.90	8.79
26°	9.79	11.50	13.65	15.34	16.43	16.71	16.58	15.74	14.26	12.30	10.31	9.27
24°	10.20	11.89	13.90	15.43	16.37	16.59	16.47	15.78	14.45	12.64	10.71	9.73
22°	10.70	11.30	14.16	15.51	16.32	16.47	16.37	15.81	14.64	12.98	11.11	10.20
20°	11.19	12.71	14.41	15.60	16.27	16.36	16.27	15.85	14.83	13.31	11.61	10.68
18°	11.60	13.02	14.60	15.62	16.11	16.14	16.09	15.79	14.94	13.58	12.02	11.12
16°	12.00	13.32	14.69	15.64	15.99	15.92	15.91	15.72	15.04	13.85	12.43	11.57
14°	12.41	13.62	14.89	15.65	15.83	15.70	15.72	15.65	15.14	14.12	12.84	12.02
12°	12.82	13.93	15.08	15.66	15.67	15.48	15.53	15.58	15.24	14.38	13.25	12.47
10°	13.22	14.24	15.26	15.68	15.51	15.26	15.34	15.51	15.34	14.66	13.56	12.88
8°	13.58	14.50	15.34	15.59	15.29	14.99	15.09	15.39	15.34	14.81	13.86	13.27
6°	13.94	14.76	15.42	15.42	15.07	14.71	14.85	15.23	15.34	14.96	14.17	13.66
4°	14.30	15.01	15.50	15.50	14.85	14.44	14.59	15.07	15.34	15.11	14.48	14.05
2°	14.65	15.26	15.59	15.34	14.63	14.17	14.33	14.91	15.34	15.27	14.79	14.44
0°	15.00	15.51	15.68	15.26	14.41	13.90	14.07	14.75	15.34	15.42	15.09	14.83

TABLE I bis - R_A

Solar radiation on a horizontal surface at the limit of the atmosphere expressed as mm of evaporable water and for a solar constant = 2.00 cal.cm².min^{-1}

Southern Hemisphere

Lat S	J	F	M	A	M	J	J	A	S	O	N	D
50°	17.54	14.66	10.85	7.03	4 24	3.05	3.47	5.51	8 90	12.88	16.53	18.22
48°	17.61	14.86	11.19	7.47	4.73	3.51	3.95	5.99	9 32	13.15	16.60	18.24
46°	17.68	15.06	11.53	7.91	5.22	3.97	4.43	6.47	9.74	13.43	16.67	18.26
44°	17.75	15.27	11.87	8.35	5.71	4.43	4.90	6.94	10.16	13.70	16.73	18.28
42°	17.82	15.47	12.21	8.80	6.12	4.89	5.38	7.42	10.59	13 97	16.80	18.29
40°	17.88	15.68	12.54	9.24	6.61	5.34	5.85	7.88	11 02	14.24	16.87	18.31
38°	17.86	15.82	12.84	9.64	7.07	5.83	6.31	8 32	11 36	14.44	16.95	18.25
36°	17.85	15.96	13.15	10.05	7.53	6.32	6.77	8 76	11.70	14.64	17.04	18.20
34°	17.84	16.10	13.45	10.46	7.99	6.81	7.23	9 20	12.04	14.85	17.12	18.15
32°	17.82	16.23	13.76	10.87	8.45	7.30	7.68	9 64	12.37	15 05	17.21	18.10
30°	17.80	16.36	14 07	11.27	8.90	7.80	8.14	10.09	12.71	15.26	17.29	18.05
28°	17.70	16.39	14.25	11.61	9.32	8.24	8 60	10.47	12.95	15 36	17.22	17.92
26°	17.60	16.43	14.44	11.95	9.74	8.68	9.06	10.85	13.19	15.46	17.15	17.79
24°	17.50	16.46	14.62	12.29	10.16	9.12	9.52	11.22	13.43	15 56	17.08	17.65
22°	17.40	16.50	14.80	12.63	10.59	9.56	9.97	11.59	13.66	15 66	17.01	17.51
20°	17.29	16.53	15.00	12.97	11.02	10.00	10.42	11.95	13.90	15.76	16.95	17.37
18°	17.11	16.47	15.10	13.22	11.37	10.40	10.81	12.26	14.09	15.78	16.80	17.10
16°	16.93	16.42	15.20	13.48	11.73	10.80	11.20	12.56	14.28	15.79	16.65	16.83
14°	16.74	16.37	15.31	13.73	12.09	11.21	11.59	12.87	14.47	15.81	16.50	16.61
12°	16.55	16.32	15.41	13.98	12.45	11.62	11.98	13.17	14.65	15.83	16.35	16.49
10°	16.36	16.27	15.51	14.24	12.80	12.03	12.37	13.48	14.83	15.85	16.19	16.27
8°	16.08	16.11	15.54	14.44	13.12	12.40	12.71	13.73	14.93	15.76	15.97	15.99
6°	15.81	15.96	15.58	14.65	13.44	12.77	13.05	13.99	15.03	15.67	15.75	15.70
4°	15.54	15.81	15.62	14.85	13.76	13.15	13.39	14.25	15.13	15.59	15.53	15.41
2°	15.27	15.66	15.65	15.05	14.08	13.51	13.73	14.50	15.24	15.50	15.31	15.12
0°	15.00	15.51	15.68	15.26	14.41	13.90	14.07	14.75	15.34	15.42	15.09	14.83

TABLE II - N

Daily average month by month of the astronomically possible sunshine duration in hours and tenths

Northern Lats.	J	F	M	A	M	J	J	A	S	O	N	D
Southern Lats.	J	A	S	O	N	D	J	F	M	A	M	J
50°	8.5	10.1	11.8	13.8	15.4	16.3	15.9	14.5	12.7	10.8	9.1	8.1
48°	8.8	10.2	11.8	13.6	15.2	16.0	15.6	14.3	12.6	10.9	9.3	8.3
46°	9.1	10.4	11.9	13.5	14.9	15.7	15.4	14.2	12.6	10.9	9.5	8.7
44°	9.3	10.5	11.9	13.4	14.7	15.4	15.2	14.0	12.6	11.0	9.7	8.9
42°	9.4	10.6	11.9	13.4	14.6	15.2	14.9	13.9	12.9	11.1	9.8	9.1
40°	9.6	10.7	11.9	13.3	14.4	15.0	14.7	13.7	12.5	11.2	10.0	9.3
35°	10.1	11.0	11.9	13.1	14.0	14.5	14.3	13.5	12.4	11.3	10.3	9.8
30°	10.4	11.1	12.0	12.9	13.6	14.0	13.9	13.2	12.4	11.5	10.6	10.2
25°	10.7	11.3	12.0	12.7	13.3	13.7	13.5	13.0	12.3	11.6	10.9	10.6
20°	11.0	11.5	12.0	12.6	13.1	13.3	13.2	12.8	12.3	11.7	11.2	10.9
15°	11.3	11.6	12.0	12.5	12.8	13.0	12.9	12.6	12.2	11.8	11.4	11.2
10°	11.6	11.8	12.0	12.3	12.6	12.7	12.6	12.4	12.1	11.8	11.6	11.5
5°	11.8	11.9	12.0	12.2	12.3	12.4	12.3	12.3	12.1	12.0	11.9	11.8
0°	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1

TABLE III - $\frac{n}{N}$

$(a + b \frac{n}{N})$ x 0.75 for potential evapotranspiration of vegetal cover

$(a + b \frac{n}{N})$ x 0.95 for evaporation from free water

A. Temperate regions - a = 0.18 b = 0.55

n/N	0.18 + 0.55 n/N	x0.75	x0.95	n/N	0.18 + 0.55 n/N	x0.75	x0.95	n/N	0.18 + 0.55 n/N	x0.75	x0.95
0.01	0.19	0.14	0.18	0.34	0.37	0.28	0.35	0.67	0.55	0.41	0.52
0.02	0.19	0.14	0.18	0.35	0.37	0.28	0.35	0.68	0.55	0.42	0.53
0.03	0.20	0.15	0.19	0.36	0.38	0.28	0.36	0.69	0.56	0.42	0.53
0.04	0.20	0.15	0.19	0.37	0.38	0.29	0.36	0.70	0.57	0.42	0.54
0.05	0.21	0.16	0.20	0.38	0.39	0.29	0.37	0.71	0.57	0.43	0.54
0.06	0.21	0.16	0.20	0.39	0.39	0.30	0.37	0.72	0.58	0.43	0.55
0.07	0.22	0.16	0.21	0.40	0.40	0.30	0.38	0.73	0.58	0.44	0.55
0.08	0.22	0.17	0.21	0.41	0.41	0.30	0.39	0.74	0.59	0.44	0.56
0.09	0.23	0.17	0.22	0.42	0.41	0.31	0.39	0.75	0.59	0.44	0.56
0.10	0.24	0.18	0.22	0.43	0.42	0.31	0.40	0.76	0.60	0.45	0.57
0.11	0.24	0.18	0.23	0.44	0.42	0.32	0.40	0.77	0.60	0.45	0.57
0.12	0.25	0.18	0.23	0.45	0.43	0.32	0.41	0.78	0.61	0.46	0.58
0.13	0.25	0.19	0.24	0.46	0.43	0.32	0.41	0.79	0.61	0.46	0.58
0.14	0.26	0.19	0.24	0.47	0.44	0.33	0.42	0.80	0.62	0.47	0.59
0.15	0.26	0.20	0.25	0.48	0.44	0.33	0.42	0.81	0.63	0.47	0.59
0.16	0.27	0.20	0.25	0.49	0.45	0.34	0.43	0.82	0.63	0.47	0.60
0.17	0.27	0.21	0.26	0.50	0.46	0.34	0.43	0.83	0.64	0.48	0.60
0.18	0.28	0.21	0.27	0.51	0.46	0.35	0.44	0.84	0.64	0.48	0.61
0.19	0.28	0.21	0.27	0.52	0.47	0.35	0.44	0.85	0.65	0.49	0.62
0.20	0.29	0.22	0.28	0.53	0.47	0.35	0.45	0.86	0.65	0.49	0.62
0.21	0.30	0.22	0.28	0.54	0.48	0.36	0.45	0.87	0.66	0.50	0.63
0.22	0.30	0.23	0.29	0.55	0.48	0.36	0.46	0.88	0.66	0.50	0.63
0.23	0.31	0.23	0.29	0.56	0.49	0.37	0.46	0.89	0.67	0.50	0.64
0.24	0.31	0.23	0.30	0.57	0.49	0.37	0.47	0.90	0.68	0.51	0.64
0.25	0.32	0.24	0.30	0.58	0.50	0.37	0.47	0.91	0.68	0.51	0.65
0.26	0.32	0.24	0.31	0.59	0.50	0.38	0.48	0.92	0.69	0.51	0.65
0.27	0.33	0.25	0.31	0.60	0.51	0.38	0.48	0.93	0.69	0.52	0.66
0.28	0.33	0.25	0.32	0.61	0.52	0.39	0.49	0.94	0.70	0.52	0.66
0.29	0.34	0.25	0.32	0.62	0.52	0.39	0.49	0.95	0.70	0.53	0.67
0.30	0.35	0.26	0.33	0.63	0.53	0.39	0.50	0.96	0.71	0.53	0.67
0.31	0.35	0.26	0.33	0.64	0.53	0.40	0.51	0.97	0.71	0.54	0.68
0.32	0.36	0.27	0.34	0.65	0.54	0.40	0.51	0.98	0.72	0.54	0.68
0.33	0.36	0.27	0.34	0.66	0.54	0.41	0.52	0.99	0.72	0.54	0.69
								1.00	0.73	0.55	0.69

TABLE III - $\frac{n}{N}$

$[a + b \frac{n}{N}]$ x 0.75 for potential evapotranspiration of vegetal cover

$[a + b \frac{n}{N}]$ x 0.95 for evaporation from free water

B. Dry tropical zones - a = 0.25 b = 0.45

n/N	0.25 + 0.45 n/N	x0.75	x0.95	n/N	0.25 + 0.45 n/N	x0.75	x0.95	n/N	0.25 + 0.45 n/N	x0.75	x0.95
0.01	0.25	0.19	0.24	0.34	0.40	0.30	0.38	0.67	0.55	0.41	0.52
0.02	0.26	0.19	0.25	0.35	0.41	0.31	0.39	0.68	0.56	0.42	0.53
0.03	0.26	0.20	0.25	0.36	0.41	0.31	0.39	0.69	0.56	0.42	0.53
0.04	0.27	0.20	0.25	0.37	0.42	0.31	0.40	0.70	0.57	0.42	0.54
0.05	0.27	0.20	0.26	0.38	0.42	0.32	0.40	0.71	0.57	0.43	0.54
0.06	0.28	0.21	0.26	0.39	0.43	0.32	0.40	0.72	0.57	0.43	0.55
0.07	0.28	0.21	0.27	0.40	0.43	0.32	0.41	0.73	0.58	0.43	0.55
0.08	0.29	0.21	0.27	0.41	0.43	0.33	0.41	0.74	0.58	0.44	0.55
0.09	0.29	0.22	0.28	0.42	0.44	0.33	0.42	0.75	0.59	0.44	0.56
0.10	0.30	0.22	0.28	0.43	0.44	0.33	0.42	0.76	0.59	0.44	0.56
0.11	0.30	0.22	0.28	0.44	0.45	0.34	0.43	0.77	0.60	0.45	0.57
0.12	0.30	0.23	0.29	0.45	0.45	0.34	0.43	0.78	0.60	0.45	0.57
0.13	0.31	0.23	0.29	0.46	0.46	0.34	0.43	0.79	0.61	0.45	0.58
0.14	0.31	0.23	0.30	0.47	0.46	0.35	0.44	0.80	0.61	0.46	0.58
0.15	0.32	0.24	0.30	0.48	0.47	0.35	0.44	0.81	0.61	0.46	0.58
0.16	0.32	0.24	0.31	0.49	0.47	0.35	0.45	0.82	0.62	0.46	0.59
0.17	0.33	0.24	0.31	0.50	0.48	0.36	0.45	0.83	0.62	0.47	0.59
0.18	0.33	0.25	0.31	0.51	0.48	0.36	0.46	0.84	0.63	0.47	0.60
0.19	0.34	0.25	0.32	0.52	0.48	0.36	0.46	0.85	0.63	0.47	0.60
0.20	0.34	0.26	0.32	0.53	0.49	0.37	0.46	0.86	0.64	0.48	0.61
0.21	0.34	0.26	0.33	0.54	0.49	0.37	0.47	0.87	0.64	0.48	0.61
0.22	0.35	0.26	0.33	0.55	0.50	0.37	0.47	0.88	0.65	0.48	0.61
0.23	0.35	0.27	0.34	0.56	0.50	0.38	0.48	0.89	0.65	0.49	0.62
0.24	0.36	0.27	0.34	0.57	0.51	0.38	0.48	0.90	0.66	0.49	0.62
0.25	0.36	0.27	0.34	0.58	0.51	0.38	0.49	0.91	0.66	0.49	0.63
0.26	0.37	0.28	0.35	0.59	0.52	0.39	0.49	0.92	0.66	0.50	0.63
0.27	0.37	0.28	0.35	0.60	0.52	0.39	0.49	0.93	0.67	0.50	0.64
0.28	0.38	0.28	0.36	0.61	0.52	0.39	0.50	0.94	0.67	0.50	0.64
0.29	0.38	0.29	0.36	0.62	0.53	0.40	0.50	0.95	0.68	0.51	0.64
0.30	0.39	0.29	0.37	0.63	0.53	0.40	0.51	0.96	0.68	0.51	0.65
0.31	0.39	0.29	0.37	0.64	0.54	0.40	0.51	0.97	0.69	0.51	0.65
0.32	0.39	0.30	0.37	0.65	0.54	0.41	0.52	0.98	0.69	0.52	0.66
0.33	0.40	0.30	0.38	0.66	0.55	0.41	0.52	0.99	0.70	0.52	0.66
								1	0.70	0.53	0.67

TABLE III - $\frac{n}{N}$

$\cdot\ b\ \frac{n}{N}]$ ⟨ × 0.75 for potential evapotranspiration of vegetal cover; × 0.95 for evaporation from free water

C. Humid tropical zones - a = 0.29 b = 0.42

n/N	0.29 + 0.42 n/N	x0.75	x0.95	n/N	0.29 + 0.42 n/N	x0.75	x0.95	n/N	0.29 + 0.42 n/N	x0.75	x0.95
0.01	0.29	0.22	0.28	0.34	0.43	0.32	0.41	0.67	0.57	0.43	0.54
0.02	0.30	0.22	0.28	0.35	0.44	0.33	0.42	0.68	0.58	0.43	0.55
0.03	0.30	0.23	0.29	0.36	0.44	0.33	0.42	0.69	0.58	0.43	0.55
0.04	0.31	0.23	0.29	0.37	0.45	0.33	0.42	0.70	0.58	0.44	0.55
0.05	0.31	0.23	0.30	0.38	0.45	0.34	0.43	0.71	0.59	0.44	0.56
0.06	0.32	0.24	0.30	0.39	0.45	0.34	0.43	0.72	0.59	0.44	0.56
0.07	0.32	0.24	0.30	0.40	0.46	0.34	0.44	0.73	0.60	0.45	0.57
0.08	0.32	0.24	0.31	0.41	0.46	0.35	0.44	0.74	0.60	0.45	0.57
0.09	0.33	0.25	0.31	0.42	0.47	0.35	0.44	0.75	0.61	0.45	0.57
0.10	0.33	0.25	0.32	0.43	0.47	0.35	0.45	0.76	0.61	0.46	0.58
0.11	0.34	0.25	0.32	0.44	0.47	0.36	0.45	0.77	0.61	0.46	0.58
0.12	0.34	0.26	0.32	0.45	0.48	0.36	0.46	0.78	0.62	0.46	0.59
0.13	0.34	0.26	0.33	0.46	0.48	0.36	0.46	0.79	0.62	0.47	0.59
0.14	0.35	0.26	0.33	0.47	0.49	0.37	0.46	0.80	0.63	0.47	0.59
0.15	0.35	0.26	0.34	0.48	0.49	0.37	0.47	0.81	0.63	0.47	0.60
0.16	0.36	0.27	0.34	0.49	0.50	0.37	0.47	0.82	0.63	0.48	0.60
0.17	0.36	0.27	0.34	0.50	0.50	0.38	0.48	0.83	0.64	0.48	0.61
0.18	0.37	0.27	0.35	0.51	0.50	0.38	0.48	0.84	0.64	0.48	0.61
0.19	0.37	0.28	0.35	0.52	0.51	0.38	0.48	0.85	0.65	0.49	0.61
0.20	0.37	0.28	0.36	0.53	0.51	0.38	0.49	0.86	0.65	0.49	0.62
0.21	0.38	0.28	0.36	0.54	0.52	0.39	0.49	0.87	0.66	0.49	0.62
0.22	0.38	0.29	0.36	0.55	0.52	0.39	0.49	0.88	0.66	0.49	0.63
0.23	0.39	0.29	0.37	0.56	0.53	0.39	0.50	0.89	0.66	0.50	0.63
0.24	0.39	0.29	0.37	0.57	0.53	0.40	0.50	0.90	0.67	0.50	0.63
0.25	0.40	0.30	0.38	0.58	0.53	0.40	0.51	0.91	0.67	0.50	0.64
0.26	0.40	0.30	0.38	0.59	0.54	0.40	0.51	0.92	0.68	0.51	0.64
0.27	0.40	0.30	0.38	0.60	0.54	0.41	0.51	0.93	0.68	0.51	0.65
0.28	0.41	0.31	0.39	0.61	0.55	0.41	0.52	0.94	0.68	0.51	0.65
0.29	0.41	0.31	0.39	0.62	0.55	0.41	0.52	0.95	0.69	0.52	0.65
0.30	0.42	0.31	0.40	0.63	0.55	0.42	0.53	0.96	0.69	0.52	0.66
0.31	0.42	0.32	0.40	0.64	0.56	0.42	0.53	0.97	0.70	0.52	0.66
0.32	0.42	0.32	0.40	0.65	0.56	0.42	0.53	0.98	0.70	0.53	0.67
0.33	0.43	0.32	0.41	0.66	0.57	0.43	0.54	0.99	0.71	0.53	0.67
								1.00	0.71	0.53	0.67

TABLE X

Table giving $\frac{\Delta}{\gamma} \times \frac{po}{p}$ in function of T°C
and standard elevation in metres above or below sea level

Elevation in metres

T°C	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
0	0.86	0.88	0.90	0.93	0.95	0.97	1.00	1.03	1.05	1.08	1.11
1	0.92	0.94	0.96	0.99	1.01	1.04	1.07	1.09	1.12	1.15	1.18
2	0.97	1.00	1.03	1.05	1.07	1.10	1.13	1.16	1.20	1.23	1.26
3	1.04	1.07	1.09	1.12	1.15	1.18	1.21	1.24	1.27	1.31	1.34
4	1.11	1.13	1.16	1.19	1.22	1.25	1.29	1.32	1.36	1.39	1.43
5	1.17	1.21	1.24	1.27	1.30	1.33	1.37	1.40	1.44	1.48	1.51
6	1.25	1.28	1.31	1.35	1.38	1.41	1.45	1.49	1.53	1.57	1.61
7	1.33	1.36	1.40	1.43	1.47	1.51	1.55	1.59	1.63	1.67	1.71
8	1.41	1.45	1.48	1.52	1.56	1.60	1.64	1.69	1.73	1.77	1.82
9	1.50	1.54	1.58	1.62	1.66	1.70	1.74	1.79	1.84	1.88	1.93
10	1.59	1.63	1.67	1.72	1.76	1.80	1.85	1.90	1.95	2.00	2.05
11	1.68	1.73	1.77	1.82	1.86	1.91	1.96	2.01	2.07	2.12	2.17
12	1.78	1.83	1.87	1.92	1.97	2.02	2.07	2.13	2.18	2.24	2.30
13	1.89	1.94	1.99	2.04	2.09	2.14	2.20	2.26	2.32	2.37	2.43
14	2.00	2.05	2.10	2.16	2.21	2.26	2.32	2.39	2.45	2.51	2.58
15	2.11	2.17	2.22	2.28	2.34	2.40	2.46	2.53	2.59	2.66	2.72
16	2.24	2.30	2.36	2.42	2.48	2.54	2.61	2.68	2.75	2.82	2.89
17	2.37	2.43	2.50	2.56	2.62	2.69	2.76	2.84	2.91	2.98	3.06
18	2.51	2.57	2.64	2.71	2.77	2.84	2.92	3.00	3.08	3.15	3.23
19	2.65	2.72	2.79	2.86	2.93	3.00	3.08	3.17	3.25	3.33	3.42
20	2.80	2.87	2.94	3.02	3.09	3.17	3.26	3.34	3.43	-	-
21	2.95	3.03	3.11	3.19	3.26	3.35	3.44	3.53	-	-	-
22	3.11	3.19	3.28	3.36	3.44	3.53	3.62	-	-	-	-
23	3.29	3.37	3.46	3.55	3.63	3.72	-	-	-	-	-
24	3.46	3.55	3.64	3.74	3.83	-	-	-	-	-	-
25	3.64	3.74	3.84	3.94	-	-	-	-	-	-	-
26	3.84	3.94	4.04	-							
27	4.04	4.15	-								
28	4.25	-									
29	-										

TABLE X

Table giving $\frac{\Delta}{\gamma} \times \frac{po}{p}$ in function of T°C and standard elevation in metres above or below sea level

Elevation in metres

T°C	-400	-200	0	200	400	600	800	1000	1200	1400	1600	1800
0	0.63	0.65	0.67	0.69	0.71	0.72	0.74	0.76	0.78	0.80	0.82	0.84
1	0.68	0.70	0.72	0.74	0.75	0.77	0.79	0.81	0.83	0.85	0.87	0.89
2	0.72	0.74	0.76	0.78	0.80	0.82	0.84	0.86	0.88	0.91	0.93	0.95
3	0.77	0.79	0.81	0.83	0.86	0.88	0.90	0.92	0.94	0.97	0.99	1.01
4	0.83	0.85	0.87	0.89	0.91	0.93	0.96	0.98	1.00	1.03	1.05	1.08
5	0.88	0.90	0.92	0.94	0.97	0.99	1.01	1.04	1.07	1.09	1.12	1.15
6	0.94	0.96	0.98	1.00	1.03	1.05	1.08	1.10	1.13	1.16	1.19	1.22
7	1.00	1.02	1.04	1.07	1.09	1.12	1.15	1.17	1.21	1.24	1.27	1.30
8	1.07	1.09	1.11	1.13	1.16	1.19	1.22	1.25	1.28	1.31	1.35	1.38
9	1.11	1.14	1.17	1.20	1.23	1.26	1.29	1.32	1.36	1.39	1.43	1.46
10	1.19	1.22	1.25	1.28	1.31	1.34	1.37	1.41	1.44	1.48	1.52	1.55
11	1.26	1.29	1.32	1.35	1.39	1.42	1.45	1.49	1.53	1.57	1.61	1.65
12	1.34	1.37	1.40	1.43	1.47	1.50	1.54	1.57	1.62	1.66	1.70	1.74
13	1.42	1.45	1.48	1.52	1.55	1.59	1.63	1.67	1.71	1.76	1.80	1.84
14	1.51	1.54	1.57	1.61	1.64	1.68	1.72	1.77	1.81	1.86	1.91	1.95
15	1.58	1.62	1.66	1.70	1.74	1.78	1.82	1.87	1.92	1.97	2.02	2.06
16	1.68	1.72	1.76	1.80	1.85	1.89	1.94	1.98	2.04	2.09	2.14	2.19
17	1.76	1.81	1.86	1.91	1.95	2.00	2.05	2.10	2.15	2.21	2.26	2.32
18	1.87	1.92	1.97	2.02	2.06	2.11	2.17	2.22	2.28	2.33	2.39	2.45
19	1.98	2.03	2.08	2.13	2.18	2.23	2.29	2.34	2.40	2.47	2.53	2.59
20	2.07	2.13	2.19	2.25	2.30	2.36	2.42	2.47	2.54	2.60	2.67	2.73
21	2.22	2.27	2.32	2.37	2.43	2.49	2.55	2.61	2.68	2.75	2.82	2.88
22	2.32	2.38	2.44	2.50	2.56	2.63	2.69	2.75	2.83	2.90	2.97	3.04
23	2.46	2.52	2.58	2.64	2.71	2.77	2.84	2.90	2.98	3.06	3.13	3.21
24	2.60	2.66	2.72	2.78	2.85	2.92	2.99	3.06	3.14	3.22	3.30	3.38
25	2.72	2.79	2.86	2.93	3.00	3.08	3.15	3.22	3.31	3.40	3.48	3.56
26	2.85	2.93	3.01	3.09	3.16	3.24	3.32	3.40	3.49	3.58	3.66	3.75
27	3.01	3.09	3.17	3.25	3.33	3.41	3.49	3.57	3.67	3.76	3.86	3.95
28	3.18	3.26	3.34	3.42	3.50	3.59	3.67	3.76	3.86	3.96	4.06	4.15
29	3.35	3.43	3.51	3.60	3.68	3.77	3.86	3.95	4.06	4.17	4.27	4.37
30	3.51	3.60	3.69	3.78	3.87	3.97	4.06	4.16	4.27	4.38	4.49	-
31	3.68	3.78	3.88	3.98	4.07	4.17	4.27	4.37	4.49	4.60	-	
32	3.87	3.97	4.07	4.18	4.28	4.38	4.49	4.59	4.71	-		
33	4.07	4.17	4.27	4.38	4.48	4.59	4.70	4.81	-			
34	4.26	4.37	4.48	4.59	4.70	4.82	4.93	-				
35	4.47	4.59	4.71	4.83	4.95	5.06	-					

TABLE IX - U

Evaporation of a free water surface

Expression 0.26 (0.5 + 0.75.U) where wind speed (U) is expressed in m/sec for $14^{o}C < T_M - T_m \leq 15^{o}C$

U	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0.130	0.150	0.169	0.189	0.208	0.228	0.247	0.267	0.286	0.306
1	0.325	0.345	0.364	0.384	0.403	0.423	0.442	0.462	0.481	0.501
2	0.520	0.540	0.559	0.579	0.598	0.618	0.637	0.657	0.676	0.696
3	0.715	0.735	0.754	0.774	0.793	0.813	0.832	0.852	0.871	0.891
4	0.910	0.930	0.949	0.969	0.988	1.008	1.027	1.047	1.066	1.086
5	1.105	1.125	1.144	1.164	1.183	1.203	1.222	1.242	1.261	1.281
6	1.300	1.320	1.339	1.359	1.378	1.398	1.417	1.437	1.456	1.476
7	1.495	1.515	1.534	1.554	1.573	1.593	1.612	1.632	1.651	1.671
8	1.690	1.710	1.729	1.749	1.768	1.788	1.807	1.827	1.846	1.866
9	1.885	1.905	1.924	1.944	1.963	1.983	2.002	2.022	2.041	2.061
10	2.080	2.100	2.119	2.139	2.158	2.178	2.197	2.217	2.236	2.256
11	2.275									

Expression 0.26 (0.5 + 0.82.U) where wind speed (U) is expressed in m/sec for $15^{o}C < T_M - T_m \leq 16^{o}C$

U	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0.130	0.151	0.173	0.194	0.215	0.237	0.258	0.279	0.301	0.322
1	0.343	0.365	0.386	0.407	0.428	0.450	0.471	0.492	0.514	0.535
2	0.556	0.578	0.599	0.620	0.642	0.663	0.684	0.706	0.727	0.748
3	0.770	0.791	0.812	0.834	0.855	0.876	0.898	0.919	0.940	0.961
4	0.983	1.004	1.025	1.047	1.068	1.089	1.111	1.132	1.153	1.175
5	1.196	1.217	1.239	1.260	1.281	1.303	1.324	1.345	1.367	1.388
6	1.409	1.431	1.452	1.473	1.494	1.516	1.537	1.558	1.580	1.601
7	1.622	1.644	1.665	1.686	1.708	1.729	1.750	1.772	1.793	1.814
8	1.836	1.857	1.878	1.900	1.921	1.942	1.964	1.985	2.006	2.027
9	2.049	2.070	2.091	2.113	2.134	2.155	2.177	2.198	2.219	2.241
10	2.262	2.283	2.305	2.326	2.347	2.369	2.390	2.411	2.433	2.454
11	2.475									

Expression 0.26 (0.5 + 0.89.U) where wind speed (U) is expressed in m/sec for $16^{o}C < T_M - T_m$

U	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0.130	0.153	0.176	0.199	0.223	0.246	0.269	0.292	0.315	0.338
1	0.361	0.385	0.408	0.431	0.454	0.477	0.500	0.523	0.547	0.570
2	0.593	0.616	0.639	0.662	0.685	0.709	0.732	0.755	0.778	0.801
3	0.824	0.847	0.870	0.894	0.917	0.940	0.963	0.986	1.009	1.032
4	1.056	1.079	1.102	1.125	1.148	1.171	1.194	1.218	1.241	1.264
5	1.287	1.310	1.333	1.356	1.380	1.403	1.426	1.449	1.472	1.495
6	1.518	1.542	1.565	1.588	1.611	1.634	1.657	1.680	1.704	1.727
7	1.750	1.773	1.796	1.819	1.842	1.866	1.889	1.912	1.935	1.958
8	1.981	2.004	2.027	2.051	2.074	2.097	2.120	2.143	2.166	2.189
9	2.213	2.236	2.259	2.282	2.305	2.328	2.351	2.375	2.398	2.421
10	2.444	2.467	2.490	2.513	2.537	2.560	2.583	2.606	2.629	2.652
11	2.675									

TABLE IX - U

Evaporation of a free water surface

Expression 0.26 (0.5 + 0.75.U) where wind speed (U) is expressed in m/sec
for 14°C < $T_M - T_m \leq$ 15°C

U	0.0	0.1	0.2	0.3	0.4	0 5	0.6	0 7	0.8	0.9
0	0 130	0.150	0.169	0.189	0.208	0.228	0 247	0.267	0.286	0.306
1	0.325	0.345	0.364	0.384	0.403	0.423	0.442	0.462	0.481	0.501
2	0.520	0.540	0.559	0.579	0.598	0.618	0.637	0.657	0.676	0.696
3	0.715	0.735	0.754	0.774	0.793	0.813	0.832	0.852	0.871	0.891
4	0.910	0.930	0.949	0.969	0.988	1.008	1.027	1.047	1.066	1.086
5	1.105	1.125	1.144	1.164	1.183	1.203	1.222	1 242	1.261	1.281
6	1.300	1.320	1.339	1.359	1.378	1.398	1.417	1.437	1.456	1.476
7	1.495	1.515	1.534	1.554	1.573	1.593	1.612	1 632	1.651	1.671
8	1.690	1.710	1.729	1.749	1 768	1.788	1.807	1.827	1.846	1.866
9	1.885	1.905	1.924	1.944	1.963	1.983	2.002	2.022	2.041	2.061
10	2.080	2.100	2.119	2.139	2.158	2.178	2 197	2.217	2.236	2.256
11	2.275									

Expression 0.26 (0.5 + 0.82.U) where wind speed (U) is expressed in m/sec
for 15°C < $T_M - T_m \leq$ 16°C

U	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0.130	0.151	0.173	0.194	0.215	0.237	0.258	0.279	0.301	0.322
1	0.343	0.365	0.386	0.407	0.428	0.450	0.471	0.492	0.514	0.535
2	0.556	0.578	0.599	0.620	0.642	0.663	0.684	0.706	0.727	0.748
3	0.770	0.791	0.812	0.834	0.855	0.876	0.898	0.919	0.940	0.961
4	0.983	1.004	1.025	1.047	1.068	1.089	1.111	1.132	1.153	1.175
5	1.196	1.217	1.239	1.260	1.281	1.303	1.324	1.345	1.367	1.388
6	1.409	1.431	1.452	1.473	1 494	1.516	1.537	1.558	1.580	1.601
7	1.622	1.644	1.665	1.686	1.708	1.729	1.750	1.772	1.793	1.814
8	1.836	1.857	1.878	1.900	1 921	1.942	1.964	1.985	2.006	2.027
9	2.049	2.070	2.091	2.113	2 134	2.155	2.177	2.198	2.219	2.241
10	2.262	2.283	2.305	2.326	2.347	2.369	2.390	2.411	2.433	2.454
11	2 475									

Expression 0.26 (0.5 + 0.89.U) where wind speed (U) is expressed in m/sec
for 16°C < $T_M - T_m$

U	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0.130	0.153	0.176	0.199	0.223	0.246	0.269	0 292	0.315	0.338
1	0.361	0.385	0.408	0.431	0.454	0 477	0.500	0 523	0 547	0 570
2	0.593	0.616	0.639	0.662	0.685	0.709	0 732	0.755	0.778	0.801
3	0.824	0.847	0.870	0.894	0.917	0 940	0.963	0 986	1.009	1.032
4	1.056	1 079	1 102	1.125	1 148	1.171	1.194	1.218	1 241	1.264
5	1.287	1.310	1.333	1.356	1.380	1.403	1.426	1.449	1.472	1.495
6	1.518	1.542	1.565	1.588	1.611	1.634	1.657	1.680	1.704	1.727
7	1.750	1.773	1.796	1.819	1 842	1 866	1.889	1.912	1 935	1.958
8	1.981	2.004	2 027	2.051	2.074	2 097	2 120	2 143	2 166	2 189
9	2.213	2 236	2.259	2.282	2 305	2 328	2.351	2.375	2.398	2.421
10	2 444	2.467	2 490	2.513	2.537	2 560	2 583	2.606	2 629	2 652
11	2 675									

TABLE VIII - U

Potential evapotranspiration

Expression 0.26 (1 + 0.75U) where wind speed (U) is expressed in m/sec
for 14°C < $T_M - T_m \leq$ 15°C

U	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0.260	0.280	0.299	0.319	0.338	0.358	0.377	0.397	0.416	0.436
1	0.455	0.475	0.494	0.514	0.533	0.553	0.572	0.592	0.611	0.631
2	0.650	0.670	0.689	0.709	0.728	0.748	0.767	0.787	0.806	0.826
3	0.845	0.865	0.884	0.904	0.923	0.943	0.962	0.982	1.001	1.021
4	1.040	1.060	1.079	1.099	1.118	1.138	1.157	1.177	1.196	1.216
5	1.235	1.255	1.274	1.294	1.313	1.333	1.352	1.372	1.391	1.411
6	1.430	1.450	1.469	1.489	1.508	1.528	1.547	1.567	1.586	1.606
7	1.625	1.645	1.664	1.684	1.703	1.723	1.742	1.762	1.781	1.801
8	1.820	1.840	1.859	1.879	1.898	1.918	1.937	1.957	1.976	1.996
9	2.015	2.035	2.054	2.074	2.093	2.113	2.132	2.152	2.171	2.191
10	2.210	2.230	2.249	2.269	2.288	2.308	2.327	2.347	2.366	2.386

Expression 0.26 (1 + 82U) where wind speed (U) is expressed in m/sec
for 15°C < $T_M - T_m \leq$ 16°C

U	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0.260	0.281	0.303	0.324	0.345	0.367	0.388	0.409	0.431	0.452
1	0.473	0.495	0.516	0.537	0.558	0.580	0.601	0.622	0.644	0.665
2	0.686	0.708	0.729	0.750	0.772	0.793	0.814	0.836	0.857	0.878
3	0.900	0.921	0.942	0.964	0.985	1.006	1.028	1.049	1.070	1.091
4	1.113	1.134	1.155	1.177	1.198	1.219	1.241	1.262	1.283	1.305
5	1.326	1.347	1.369	1.390	1.411	1.433	1.454	1.475	1.497	1.518
6	1.539	1.561	1.582	1.603	1.624	1.646	1.667	1.688	1.710	1.731
7	1.752	1.774	1.735	1.816	1.838	1.859	1.880	1.902	1.923	1.944
8	1.966	1.987	2.008	2.030	2.051	2.072	2.094	2.115	2.136	2.157
9	2.179	2.200	2.221	2.243	2.264	2.285	2.307	2.328	2.349	2.371
10	2.392	2.413	2.435	2.456	2.477	2.499	2.520	2.541	2.563	2.584

Expression 0.26 (1 + 0.89U) where wind speed (U) is expressed in m/sec
for 16°C < $T_M - T_m$

U	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0.260	0.283	0.306	0.329	0.353	0.376	0.399	0.422	0.445	0.468
1	0.491	0.515	0.538	0.561	0.584	0.607	0.630	0.653	0.677	0.700
2	0.723	0.746	0.769	0.792	0.815	0.839	0.862	0.885	0.908	0.931
3	0.954	0.977	1.000	1.024	1.047	1.070	1.093	1.116	1.139	1.162
4	1.186	1.209	1.232	1.255	1.278	1.301	1.324	1.348	1.371	1.394
5	1.417	1.440	1.463	1.486	1.510	1.533	1.556	1.579	1.602	1.625
6	1.648	1.672	1.695	1.718	1.741	1.764	1.787	1.810	1.834	1.857
7	1.880	1.903	1.926	1.949	1.972	1.996	2.019	2.042	2.065	2.088
8	2.111	2.134	2.157	2.181	2.204	2.227	2.750	2.273	2.296	2.319
9	2.343	2.366	2.389	2.412	2.435	2.458	2.481	2.505	2.528	2.551
10	2.574	2.597	2.620	2.643	2.667	2.690	2.713	2.736	2.759	2.782

TABLE VIII - U

Potential evapotranspiration

Expression 0.26 (1 + 0.54U) where wind speed (U) is expressed in m/sec for $T_M - T_m \leq 12^oC$

U	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0.260	0.274	0.288	0.302	0.316	0.330	0.344	0.358	0.372	0.386
1	0.400	0.414	0.428	0.443	0.457	0.471	0.485	0.499	0.513	0.527
2	0.541	0.555	0.569	0.583	0.597	0.611	0.625	0.639	0.653	0.667
3	0.681	0.695	0.709	0.723	0.737	0.751	0.765	0.779	0.794	0.808
4	0.822	0.836	0.850	0.864	0.878	0.892	0.906	0.920	0.934	0.948
5	0.962	0.976	0.990	1.004	1.018	1.032	1.046	1.060	1.074	1.088
6	1.102	1.116	1.130	1.145	1.159	1.173	1.187	1.201	1.215	1.229
7	1.243	1.257	1.271	1.285	1.299	1.313	1.327	1.341	1.355	1.369
8	1.383	1.397	1.411	1.425	1.439	1.453	1.467	1.481	1.496	1.510
9	1.524	1.538	1.552	1.566	1.580	1.594	1.608	1.622	1.636	1.650
10	1.664	1.678	1.692	1.706	1.720	1.734	1.748	1.762	1.776	1.790

Expression 0.26 (1 + 0.61U) where wind speed (U) is expressed in m/sec for $12^oC < T_M - T_m \leq 13^oC$

U	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0.260	0.276	0.292	0.308	0.323	0.339	0.355	0 371	0.387	0.403
1	0.419	0.434	0.450	0.466	0.482	0.498	0.514	0.530	0.545	0.561
2	0.577	0.593	0.609	0.625	0.641	0.657	0.672	0 688	0.704	0 720
3	0 736	0.752	0.768	0 783	0.799	0.815	0.831	0.847	0 863	0.879
4	0.894	0.910	0.926	0.942	0.958	0.974	0.990	1.005	1.021	1.037
5	1.053	1.069	1.085	1.101	1.116	1.132	1.148	1.164	1.180	1 196
6	1 212	1.227	1.243	1.259	1.275	1.291	1.307	1.323	1.338	1.354
7	1.370	1.386	1.402	1.418	1.434	1.450	1.465	1.481	1.497	1.513
8	1.529	1.545	1.561	1.576	1.592	1.608	1.624	1 640	1 656	1 672
9	1 687	1.703	1.719	1.735	1.751	1.767	1.783	1.798	1 814	1.830
10	1.846	1.862	1 878	1.894	1.909	1.925	1.941	1 957	1 973	1 989

Expression 0.26 (1 + 0.68U) where wind speed (U) is expressed in m/sec for $13^oC < T_M - T_m \leq 14^oC$

U	0 0	0.1	0.2	0.3	0.4	0.5	0.6	0 7	0 8	0 9
0	0 260	0.278	0.295	0.313	0.331	0.348	0.366	0.384	0.401	0.419
1	0.437	0.454	0.472	0.490	0.508	0.525	0.543	0.561	0.578	0 596
2	0 614	0.631	0.649	0.667	0.684	0.702	0.720	0.737	0.755	0 773
3	0.790	0.808	0.826	0.843	0.861	0.879	0.896	0.914	0.932	0.950
4	0 967	0.985	1.003	1.020	1.038	1.056	1.073	1.091	1.109	1.126
5	1 144	1.162	1.179	1.197	1.215	1.232	1.250	1.268	1.285	1.303
6	1 321	1.338	1.356	1.374	1 392	1.409	1.427	1.445	1.462	1.480
7	1.498	1.515	1.533	1.551	1.568	1.586	1.604	1 621	1.639	1.657
8	1 674	1.692	1.710	1.727	1.745	1.763	1.780	1 798	1 816	1.834
9	1.851	1.869	1.887	1.904	1.922	1.940	1.957	1.975	1.993	2.010
10	2 028	2.046	2.063	2.081	2.099	2.116	2.134	2 152	2.169	2.187

TABLE VII

Saturation vapour pressure over water e_a in millibars as function of T^oC

(Smithsonian Table, 1966)

T.	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
-5	4.21	4.18	4.15	4.12	4.09	4.06	4.03	4.00	3.97	3.94
-4	4.55	4.51	4.48	4.44	4.41	4.38	4.34	4.31	4.28	4.25
-3	4.90	4.86	4.83	4.79	4.75	4.72	4.68	4.65	4.61	4.58
-2	5.28	5.24	5.20	5.16	5.12	5.08	5.05	5.01	4.97	4.93
-1	5.68	5.64	5.60	5.55	5.51	5.47	5.43	5.39	5.35	5.31
-0	6.11	6.06	6.02	5.98	5.93	5.89	5.85	5.80	5.76	5.72
0	6.11	6.15	6.20	6.24	6.29	6.33	6.38	6.43	6.47	6.52
1	6.57	6.61	6.66	6.71	6.76	6.81	6.86	6.90	6.95	7.00
2	7.05	7.11	7.16	7.21	7.26	7.31	7.36	7.42	7.47	7.52
3	7.58	7.63	7.68	7.74	7.79	7.85	7.90	7.96	8.02	8.07
4	8.13	8.19	8.24	8.30	8.36	8.42	8.48	8.54	8.60	8.66
5	8.72	8.78	8.84	8.90	8.97	9.03	9.09	9.15	9.22	9.28
6	9.35	9.41	9.48	9.54	9.61	9.67	9.74	9.81	9.88	9.94
7	10.01	10.08	10.15	10.22	10.29	10.36	10.43	10.51	10.58	10.65
8	10.72	10.80	10.87	10.94	11.02	11.09	11.17	11.24	11.32	11.40
9	11.47	11.55	11.63	11.71	11.79	11.87	11.95	12.03	12.11	12.19
10	12.27	12.36	12.44	12.52	12.61	12.69	12.78	12.86	12.95	13.03
11	13.12	13.21	13.30	13.38	13.47	13.56	13.65	13.74	13.83	13.93
12	14.02	14.11	14.20	14.30	14.39	14.49	14.58	14.68	14.77	14.87
13	14.97	15.07	15.17	15.27	15.37	15.47	15.57	15.67	15.77	15.87
14	15.98	16.08	16.19	16.29	16.40	16.50	16.61	16.72	16.83	16.94
15	17.04	17.15	17.26	17.38	17.49	17.60	17.71	17.83	17.94	18.06
16	18.17	18.29	18.41	18.53	18.64	18.76	18.88	19.00	19.12	19.25
17	19.37	19.49	19.61	19.74	19.86	19.99	20.12	20.24	20.37	20.50
18	20.63	20.76	20.89	21.02	21.16	21.29	21.42	21.56	21.69	21.83
19	21.96	22.10	22.24	22.38	22.52	22.66	22.80	22.94	23.09	23.23
20	23.37	23.52	23.66	23.81	23.96	24.11	24.26	24.41	24.56	24.71
21	24.86	25.01	25.17	25.32	25.48	25.64	25.79	25.95	26.11	26.27
22	26.43	26.59	26.75	26.92	27.08	27.25	27.41	27.58	27.75	27.92
23	28.09	28.26	28.42	28.60	28.77	28.95	29.12	29.30	29.48	29.65
24	29.83	30.01	30.19	30.37	30.56	30.74	30.92	31.11	31.30	31.48
25	31.67	31.86	32.05	32.24	32.43	32.63	32.82	33.02	33.21	33.41
26	33.61	33.81	34.01	34.21	34.41	34.62	34.82	35.03	35.23	35.44
27	35.65	35.86	36.07	36.28	36.50	36.71	36.92	37.14	37.36	37.58
28	37.80	38.02	38.24	38.46	38.69	38.91	39.14	39.37	39.59	39.82
29	40.06	40.29	40.52	40.76	40.99	41.23	41.47	41.71	41.95	42.[illegible]
30	42.43	42.67	42.92	43.17	43.41	43.66	43.91	44.17	44.42	44.67
31	44.93	45.18	45.44	45.70	45.96	46.22	46.49	46.75	47.02	47.28
32	47.55	47.82	48.09	48.36	48.64	48.91	49.19	49.47	49.75	50.03
33	50.31	50.59	50.87	51.16	51.45	51.74	52.03	52.32	52.61	52.90
34	53.20	53.50	53.80	54.10	54.40	54.70	55.00	55.31	55.62	55.93
35	56.24	56.55	56.86	57.18	57.49	57.81	58.13	58.45	58.77	59.10
36	59.42	59.75	60.08	60.41	60.74	61.07	61.41	61.74	62.08	62.42
37	62.76	63.11	63.45	63.80	64.14	64.49	64.84	65.20	65.55	65.91
38	66.26	66.62	66.99	67.35	67.71	68.08	68.45	68.82	69.19	69.56
39	69.93	70.31	70.69	71.07	71.45	71.83	72.22	72.61	73.00	73.39

TABLE VI

Expression $0.9 \frac{n}{N} + 0.1$

n/N	0.	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	n/N
0.00	0.10	0.11	0.12	0.13	0.14	0.15	0.15	0.16	0.17	0.18	0.00
0.10	0.19	0.20	0.21	0.22	0.23	0.24	0.24	0.25	0.26	0.27	0.10
0.20	0.28	0.29	0.30	0.31	0.32	0.33	0.33	0.34	0.35	0.36	0.20
0.30	0.37	0.38	0.39	0.40	0.41	0.42	0.42	0.43	0.44	0.45	0.30
0.40	0.46	0.47	0.48	0.49	0.50	0.51	0.51	0.52	0.53	0.54	0.40
0.50	0.55	0.56	0.57	0.58	0.59	0.60	0.60	0.61	0.62	0.63	0.50
0.60	0.64	0.65	0.66	0.67	0.68	0.69	0.69	0.70	0.71	0.72	0.60
0.70	0.73	0.74	0.75	0.76	0.77	0.78	0.78	0.79	0.80	0.81	0.70
0.80	0.82	0.83	0.84	0.85	0.86	0.87	0.87	0.88	0.89	0.90	0.80
0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.96	0.97	0.98	0.99	0.90
1.00	1.00										1.00

TABLE IV

Blackbody radiation (σT_K^4) expressed in mm of water in function of T°C

°C	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	11.02	11.04	11.06	11.08	11.09	11.10	11.12	11.14	11.15	11.17
1	11.18	11.20	11.22	11.24	11.25	11.26	11.28	11.30	11.31	11.33
2	11.35	11.37	11.39	11.41	11.42	11.43	11.45	11.47	11.48	11.50
3	11.51	11.53	11.55	11.57	11.58	11.59	11.61	11.63	11.64	11.66
4	11.68	11.70	11.72	11.74	11.75	11.76	11.78	11.80	11.81	11.83
5	11.85	11.87	11.89	11.90	11.92	11.94	11.96	11.97	11.98	12.00
6	12.02	12.04	12.06	12.08	12.09	12.10	12.12	12.14	12.16	12.18
7	12.20	12.22	12.24	12.26	12.27	12.29	12.31	12.32	12.34	12.36
8	12.37	12.39	12.41	12.43	12.44	12.46	12.48	12.50	12.51	12.53
9	12.55	12.57	12.59	12.60	12.62	12.64	12.66	12.67	12.69	12.71
10	12.73	12.75	12.77	12.79	12.80	12.81	12.83	12.85	12.87	12.89
11	12.91	12.93	12.95	12.97	12.99	13.01	13.02	13.04	13.06	13.08
12	13.09	13.11	13.13	13.14	13.16	13.18	13.20	13.23	13.25	13.27
13	13.28	13.30	13.32	13.34	13.35	13.37	13.39	13.41	13.43	13.45
14	13.46	13.48	13.50	13.52	13.54	13.55	13.57	13.59	13.61	13.63
15	13.65	13.67	13.69	13.71	13.73	13.74	13.76	13.78	13.80	13.82
16	13.84	13.86	13.88	13.90	13.92	13.94	13.95	13.97	13.99	14.01
17	14.03	14.05	14.07	14.09	14.11	14.13	14.15	14.17	14.19	14.21
18	14.23	14.25	14.27	14.29	14.31	14.33	14.35	14.37	14.39	14.41
19	14.43	14.45	14.47	14.49	14.51	14.53	14.54	14.56	14.58	14.60
20	14.62	14.64	14.66	14.68	14.70	14.73	14.75	14.77	14.79	14.81
21	14.83	14.85	14.87	14.89	14.91	14.93	14.95	14.97	14.99	15.01
22	15.03	15.05	15.07	15.09	15.11	15.13	15.15	15.17	15.19	15.21
23	15.23	15.25	15.27	15.29	15.31	15.34	15.36	15.38	15.40	15.42
24	15.44	15.46	15.48	15.50	15.52	15.55	15.57	15.59	15.61	15.63
25	15.65	15.67	15.69	15.71	15.73	15.76	15.78	15.80	15.82	15.84
26	15.86	15.88	15.90	15.92	15.94	15.97	15.99	16.01	16.03	16.05
27	16.07	16.09	16.11	16.14	16.16	16.18	16.20	16.22	16.25	16.27
28	16.29	16.31	16.33	16.35	16.37	16.40	16.42	16.44	16.46	16.48
29	16.50	16.52	16.54	16.57	16.59	16.61	16.63	16.65	16.68	16.70
30	16.72	16.74	16.77	16.79	16.81	16.84	16.86	16.88	16.90	16.93
31	16.95	16.97	16.99	17.02	17.04	17.06	17.08	17.10	17.13	17.15
32	17.17	17.19	17.22	17.24	17.26	17.29	17.31	17.33	17.35	17.38
33	17.40	17.42	17.45	17.47	17.49	17.52	17.54	17.56	17.58	17.61
34	17.65	17.68	17.70	17.72	17.75	17.77	17.79	17.81	17.84	17.86
35	17.88	17.90	17.93	17.95	17.97	18.00	18.02	18.04	18.07	18.09

TABLE V

Expression of $0.56 - 0.079 \sqrt{e_d}$ where e_d is vapour pressure expressed in millibars

e_d	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
5	0.38	0.38	0.38	0.38	0.38	0.37	0.37	0.37	0.37	0.37
6	0.37	0.37	0.36	0.36	0.36	0.36	0.36	0.36	0.35	0.35
7	0.35	0.35	0.35	0.35	0.34	0.34	0.34	0.34	0.34	0.34
8	0.34	0.34	0.33	0.33	0.33	0.33	0.33	0.33	0.32	0.32
9	0.32	0.32	0.32	0.32	0.32	0.32	0.31	0.31	0.31	0.31
10	0.31	0.31	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30
11	0.30	0.30	0.30	0.30	0.29	0.29	0.29	0.29	0.29	0.29
12	0.29	0.29	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
13	0.28	0.28	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
14	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
15	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
16	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
17	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
18	0.23	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
19	0.22	0.22	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
20	0.21	0.21	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
21	0.20	0.20	0.20	0.20	0.19	0.19	0.19	0.19	0.19	0.19
22	0.19	0.19	0.19	0.19	0.19	0.19	0.18	0.18	0.18	0.18
23	0.18	0.18	0.18	0.18	0.18	0.18	0.17	0.17	0.17	0.17
24	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
25	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
26	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.15
27	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14
28	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
29	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
30	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.12
31	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11
32	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
33	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
34	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.09	0.09
35	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
36	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08
37	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07
38	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
39	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06
40	0.06									

VITA

VITA

JAYAWANT D. JADHAV

A candidate for the degree

of

MASTER OF SCIENCE

in

AGRICULTURE

1991

Title of Thesis : Study of evapotranspiration of wheat crop in varying soil moisture conditions

Major field : Agricultural Meteorology

Biographical Information:

Personal : Born in Ambasun, District: Nasik, State: Maharashtra on October 15, 1964; son of Smt. Leelabai and Late Shri. Dadaji K. Patil.

Educational : Successfully completed Primary school, high school and Junior College at Rahuri, Dist: Ahmednagar. Was awarded Bachelor of Science (Agriculture) degree in first class from College of Agriculture, Dhule, constituent college of Mahatma Phule Agricultural University, Rahuri (Maharashtra) in 1988. Joined M.Sc. (Agri.) in the discipline of Agricultural Meteorology at CASAM, College of Agriculture, Pune, affiliated to the Mahatma Phule Agricultural University, Rahuri (Maharashtra). Was selected for I.C.A.R. Junior Fellowship.