

Consumptive use pattern of mustard (*Brassica Juncea L*) under different soil and climatic environments

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सार — सरसों उत्तर भारत की एक महत्वपूर्ण नकदी फसल है जहाँ कि इसे भिन्न-भिन्न जलवायु वाले पर्यावरण और मृदाओं में उगाया जाता है। प्रस्तुत अध्ययन में, सरसों के क्षयकर उपयोग तथा संबंधित पहलुओं को समझने के लिए चार कृषि-जलवायु क्षेत्रों — जोरहट, संखुटा, रायपुर और जोधपुर के लिए वाष्पोत्सर्जन एवं अन्य कृषि-जलवायु आंकड़ों का उपयोग किया गया है। लाइसिमीटर द्वारा रिकॉर्ड किए गए वाष्पोत्सर्जन के आंकड़ों, भूमंडलीय विकिरण तथा जोरहट के लिए वास्तविक मृदानमी के आंकड़ों और परिकल्पित मृदानमी का उपयोग किया गया।

अध्ययन से ज्ञात हुआ है कि सरसों का पौधा सभी स्थानों पर अधिक मात्रा में पानी का उपयोग करता है, केवल उन आर्द्र स्थानों को छोड़ कर जहाँ कि क्षयकर उपयोग न्यूनतम है। संखुटा और जोरहट के मामले में पानी का उपयोग बुवाई के बाद 31 से 60 दिनों के दौरान अधिकतम होता है। 45 से 100 मी० सतह के लिए मृदानमी के परिकल्पित आंकड़े वास्तविक आंकड़ों के साथ मेल खाते हैं। इस विश्लेषण से यह भी ज्ञात हुआ है कि बुवाई के बाद सातवें सप्ताह के दौरान क्षयकर उपयोग और भूमंडलीय विकिरण का अनुपात अधिकतम होता है। इस सूचना का उपयोग सिंचाई की आवश्यकताओं को ज्ञात करने तथा फसल में ऊर्जा संतुलन घटकों के परिकलन हेतु किया जा सकता है।

ABSTRACT. Mustard is an important cash crop in north India where it is widely grown under different climatic environment and soil types. In the present study, evapotranspiration and other agro-meteorological data for four agroclimatic locations, viz., Jorhat, Samakhunta, Raipur and Jodhpur have been utilized to understand consumptive use and related aspects of mustard. The evapotranspiration values recorded by lysimeters, global radiation and actual soil moisture data of Jorhat and the computed soil moisture have been used.

The study suggests that the mustard plant uses more water at all the stations except at humid location where consumptive use is least. The utilization is maximum between 31-60 days after sowing in case of Jorhat and Samakhunta. The computed soil moisture estimates for 45 cm layer agree with the actual soil moisture. The analysis also brings out that during the seventh week after sowing, the ratio of consumptive use and global radiation attains a maximum value. This information can be used for determining irrigation needs and computing energy balance components in the crop.

Key words — Evapotranspiration, Consumptive use, Irrigation, Soil moisture, Rainfall, Crop

1. Introduction

Mustard is an important oilseed crop of the rabi season in India and occupies first position in acreage and production in the world. It is extensively grown in north India where it is the most important edible oil and main cooking medium. It is also a cash crop. The plant is tall and erect, 90-175 cm in height, much branched and self-fertile. It grows well in areas of 25-40 cm seasonal rainfall, the crop maturity ranges from 81-118 days depending upon its geno-type. The average yield ranges from 5-7 q/hect. Mustard plant is highly susceptible to "white rust" disease and nearly 1/4th of mustard production in India is lost due to this pest. The synthesis of oil in grain begins immediately after ovary is fertilized. Flavour of *Brassica juncea* is due to the presence of 25% erucic acid and 175 micro-moles per gram of glucosinate.

Incidentally, study of this important cash crop has not received attention it deserves from the agricultural scientists. Very few studies seem to have been made on its growth and yield variability in relation to weather conditions.

Yadav and Gupta (1975) studied Indian mustard data of Ludhiana and observed that with 55 mm seasonal rainfall, the crop responds well to one irrigation 3 weeks after sowing. Sinha (1991) studied varietal performance in different soil conditions and determined ability of mustard for tolerance to soil salinity. Chakraborty *et al.* (1991) found wider row spacing result in reduced dry matter accumulation significantly, than the narrow ones. Arvind Kumar *et al.* (1992) found that water use rate by Jalshakti variety of mustard was highest, during 106-130 days after sowing. In the present study an attempt has been made to determine variability in

TABLE 1
Mustard crop characteristics

Station	Year	Variety	Date of sowing	Duration (days)	Maximum height of plant (cm)	Frequency of irrigation	Total growing season rainfall (mm)
Jorhat	1986	M-27	14-11-86	91	49.5	0	39.3
	1987	T ₃ -29	10-11-87	93	NA	1	31.4
	1988	M-27	28-10-88	95	70.1	0	61.7
	1989	M-27	23-11-89	102	NA	0	98.1
Samakhunta	1986	M-27	13-12-86	81	60.3	1	39.5
	1988	M-27	14-12-88	82	41.2	1	8.2
	1989	M-27	24-11-89	91	62.2	2	21.0
Raipur	1987	Varuna	1-12-87	106	125.3	3	49.4
	1988	Varuna	27-12-88	97	78.8	3	1.7
Jodhpur	1986	NA	15-11-86	116	NA	10	0
	1987	NA	9-11-87	113	NA	12	11.9
	1989	NA	8-11-89	115	NA	2	35.5

NA = Not available

water-use pattern by mustard under different soil and climatic conditions.

2. Data used

The study utilizes 4 years' data of Jorhat (26° 47' N, 94° 12' E, 87 m asl), 3 years at Samakhunta (21° 56' N, 86° 46' E, 50 m asl) and 2 years each at Raipur (21° 16' N, 81° 36' E, 200 m asl) and Jodhpur (26° 18' N, 73° 01' E, 224 m asl). The data used were evapotranspiration, rainfall, sunshine hours and soil moisture (SM). Average plant height was also used wherever available. For computing potential evapotranspiration (PET), temperature, humidity and wind data were utilised. The soil at Jorhat is sandy clay loam, at Samakhunta and Raipur silty clay loam, and at Jodhpur sandy loam. While Jorhat belongs to humid climatic type, Samakhunta and Raipur belong to moist sub-humid type. On the other hand, Jodhpur situated in the core of Thar, has arid climate. Details about variety, duration, maximum height of plant and number of irrigations during the crop season are given in Table 1. Soil moisture data at surface, 15, 30 and 45 cm depth were available only at Jorhat for 1987, 1988 and 1989. Hence from sowing dates, rainfall, rooting depth, soil characteristics and PET, the SM has been computed indirectly and discussed for each station. The evapotranspiration recorded by the lysimeter was assumed to represent the consumptive use of water by the crop.

3. Normal and actual weather conditions

3.1. Climatic features

Before actually discussing the results, it is worth mentioning the climate which normally prevails during rabi season and the actual weather experienced by the mustard crop. The climatic features of the four stations chosen in the study are described below:

Jorhat — This station belongs to humid climatic type. It receives about 65% of annual rainfall (of 220 cm) in southwest monsoon. During rabi season rainfall is low in quantum, *i.e.*, about 7 cm. Hence during this season, crop growth depends entirely on stored moisture.

The mean temperature during the rabi season is about 20°C with a minimum temperature of 13°C and a maximum of 27°C. The air remains humid during the season with relative humidity of about 75%.

Samakhunta — Samakhunta, as per Thornthwaite classification, falls under moist sub-humid climate. Most of the annual rainfall (of about 175 cm) occurs during monsoon months. The rabi crop season receives about 5 cm and is raised on residual moisture from kharif season. Dew formation during the rabi season provides additional moisture source.

Mean temperature during the crop season is 24°C, with 30°C as mean maximum and 19°C as the mean minimum temperature. The mean relative humidity is substantially large (about 70%).

Raipur — With well-marked dry and moist seasons, this station experiences the dry sub-humid climate. Unlike Jorhat and Samakhunta, annual rainfall is less, *i.e.*, about 140 cm, mostly occurring during the monsoon season. Post-monsoon and winter are normally dry, with occasionally light rains due to passage of systems from west.

The mean temperature during the rabi-growing period is 21°C. The maximum temperature is about 28°C, minimum 14°C and the mean relative humidity is of 50%.

Jodhpur — Jodhpur is located in the arid zone where mesophytic crops are possible only on irrigation. It receives very little annual rainfall (less than 40 cm), nearly whole of it in the monsoon season. During rabi crop season, rainfall is irregular and very low in quantum, mostly contributed by western disturbances. Dew is an important source of water to plants in this region.

The normal mean temperature during mustard season is about 20°C. The maximum is about 28°C and minimum 11°C. Mercury, however, occasionally falls even below freezing level. The climate at the station being mostly dry, the relative humidity in mustard season rarely exceeds 35%.

3.2. Actual weather conditions

Jorhat — Rainfall during the four mustard growing seasons was 39, 31, 62 and 98 mm during 1986, 1987, 1988 and 1989 respectively. Jorhat experienced high humidity in all the four years (nearly 70-80%) while mean temperature was between 16-17°C, slightly below normal.

Samakhunta — During 1987, the station recorded about 39 mm and in 1989, 21 mm rainfall in the crop season. However, during 1988 the rainfall was very low (less than 10 mm). The relative humidity was comparatively less than normal (about 60%). The mean temperature, on the other hand, was slightly lower than normal and ranged between 19 to 20°C.

Raipur — The seasonal rainfall in 1987 was substantial, about 50 mm. However, the weather remained nearly dry during crop season of 1988. Like Samakhunta, the humidity remained about

60% in both the years. The mean temperature was however nearly normal.

Jodhpur — Weather in the mustard season was dry in 1986. In 1987 some rainfall (*i.e.*, 12 mm) occurred which would have been able to meet the water demand to a limited extent. In 1989, however, the rainfall was rather large, *i.e.*, 35 mm but incidentally, occurred during post-reproduction phase when water needs are substantially low. In none of the years, the humidity exceeded 40%. The mean temperature was much below normal.

4. Methodology

4.1. Estimation of soil moisture

Rate of extraction of moisture increases as the root system develops. Olderman and Frere (1982) have suggested, from water balance technique, a method of estimating progressive soil moisture as the root system develops. This method has been followed in the study. While adopting the method, the following assumptions have been made :

- (i) Soil water content of the profile upto the rooting depth is at the field capacity.
- (ii) The moisture at the end of the week is distributed uniformly over the soil profile.
- (iii) The root system develops to a maximum depth of 45 cm.

The basic equation is

$$S_i = S_{i-1} + P_i - WR_i \quad (1)$$

where,

S_i — Water (mm) retained in the soil at the end of the i th week

S_{i-1} — Water (mm) observed in the soil at the beginning of the i th week.

P_i — Precipitation (mm) during the i th week.

The water requirement of the crop during the i th week, WR_i , is given by the equation,

$$WR_i = K_c \times PET_i \quad (2)$$

where,

PET_i — Potential evapotranspiration during the i th week and

TABLE 2
Water use pattern (mm)

Station	Year	Periodic consumptive use of water (mm)				Total seasonal ET
		0-30 days	31-60 days	61-90 days	91 days till harvest	
Jorhat	1986	17.8 (0.6)	53.1 (1.8)	26.1 (0.8)	—	97.0 (1.1)
	1987	20.1 (0.7)	54.7 (1.8)	13.5 (0.4)	—	88.3 (1.0)
	1988	25.6 (0.8)	48.0 (1.6)	26.8 (0.8)	—	100.4 (1.1)
	1989	13.1 (0.4)	47.5 (1.6)	24.6 (0.8)	1.7 (0.2)	86.9 (0.9)
Samakhunta	1986	22.9 (0.8)	111.0 (3.7)	65.5 (3.1)	—	199.4 (2.5)
	1988	32.8 (1.1)	123.7 (4.1)	90.2 (4.1)	—	246.7 (3.1)
	1989	42.1 (1.4)	116.9 (3.9)	127.9 (4.1)	—	286.9 (3.1)
Raipur	1987	14.8 (0.5)	79.4 (2.7)	119.5 (4.0)	24.1 (1.5)	237.8 (2.2)
	1988	47.1 (1.6)	122.4 (4.1)	95.2 (2.6)	—	264.7 (2.7)
Jodhpur	1986	15.7 (0.5)	33.9 (1.1)	93.3 (1.1)	36.6 (1.4)	179.5 (1.5)
	1987	26.6 (0.9)	55.3 (1.8)	109.2 (3.6)	26.6 (1.2)	217.3 (1.9)
	1989	31.4 (1.1)	78.3 (2.6)	90.3 (3.0)	19.8 (0.8)	220.1 (1.9)

N.B. — Figures in parenthesis represent rate of water use (mm/day).

K_{ci} — Crop co-efficient during the i th week.

From the first week onwards the root depth has been assumed to increase by 5 cm each week, from its initial value of 5 cm in the first week as was done by Olderman and Frere (1982). This increment of the root is assumed to progress till 9th week. During this and subsequent weeks of the crop growth till maturity, the root depth is assumed constant at 45 cm.

4.2. Global radiation computation

In this study an empirical linear model, given below has been used to compute total global radiation R_s as follows :

$$R_s = R_t(a + b n/N) \quad (3)$$

where,

R_t — Radiation received at the top of the atmosphere (measured from Smithsonian tables)

n — actual hours of sunshine

N — maximum possible hours of sunshine

a, b being numerical coefficients.

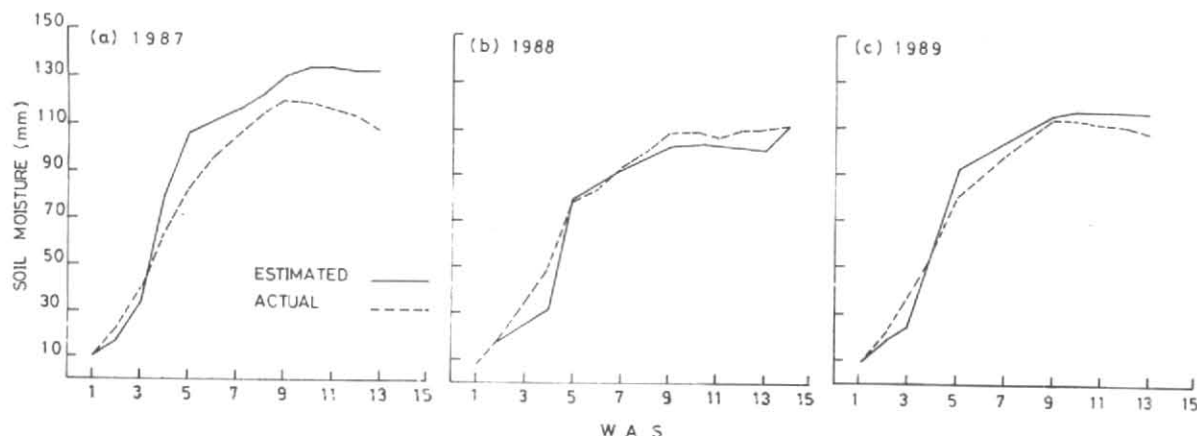
The values for a and b have been taken as those given by Ganesan (1970) for Indian locations. The radiation terms were converted from cal/cm²/day to mm of evaporable water by dividing it by 59.

5. Results and discussion

5.1. Evapotranspiration and water use pattern

The total ET used was considered as the consumptive use of the crop. Pattern of water use for each strain is given in Table 2. It is apparent that soil characteristics and the water availability, affect mustard markedly. Marginally higher consumptive use at Jorhat during 1988 than in other years was due to fairly well distributed rainfall which resulted in better crop growth.

The variety M-27 uses less than 100 mm of water at Jorhat. In spite of shorter duration and less



Figs. 1 (a-c). Actual and estimated soil moisture at Jorhat as the root system develops

rainfall, irrigation contributed to increased consumptive use of 200 mm or more by this variety at drier environment of Samakhunta (Singh *et al.* 1991). It may be mentioned that the variety M-27 generally takes longer duration for maturity at Jorhat than at Samakhunta.

Similarly at Raipur availability of water under frequently irrigation conditions contributed to high water use (*i.e.*, 240-260 mm) in both years, inspite of failure of winter rains in 1988 as may be seen in Table 1. The Varuna variety at Raipur normally not only takes longer duration than M-27 at Jorhat or Samakhunta but the plant reaches greater height than M-27.

The water-use at arid Jodhpur was also high in all three years mainly due to irrigation at regular intervals.

Higher consumptive use of water observed at Samakhunta, Raipur and Jodhpur was because of more and extensive root-zone of the crop. The chief differences between the consumptive use of mustard at these locations stem chiefly from inherent differences in plant growth on the four different soils. The sandy clay loam at Jorhat warms more rapidly during winter and spring and the mustard plants get off to a quicker start. With a field capacity of 23%, the plant has a much larger soil moisture reserve to fall back upon. This explains why irrigation is needed less frequently at Jorhat.

At the other stations the fine textured sandy silty soil warms up slowly during the mustard crop season. This results in retarded early plant growth. Thus, the soil moisture use by rabi season plants is

confined to shallow surface soil layers necessitating frequent irrigations when winter rains are inadequate, to avoid severe soil moisture stress. This explains high consumptive use of water at Samakhunta, Raipur and Jodhpur.

Periodic consumptive water use for 1-30, 30-60, 60-90 and 91 days till maturity, as the case may be, is also given in Table 2.

Maximum water use for M-27 or "Varuna" varieties appears to occur between 31-60 days after sowing. In case of Jodhpur for which information on variety sown was not available but where crop duration exceeds 110 days, maximum water intake occurs between 61-90 days from sowing and could be attributed mainly to higher evaporative demand in the later stage of crop growth (Reddy *et al.* 1988).

The increase in rate of daily water use by M-27 variety at Samakhunta is nearly 3 times than that at Jorhat. This was mainly observed after 30 days of sowing till maturity when daily water utilised at Samakhunta exceed even 4 mm. Rate of water use ranged 1-2 mm, being slightly higher at Raipur than at Jodhpur. The highest daily use at both these locations is observed in 61-90 day period.

5.2. Soil moisture extraction pattern

The soil moisture computations are shown for 1987, 1988 and 1989 in Figs. 1 (a-c) for Jorhat. For the sake of comparison actual SM values are also given. The estimated SM is seen to increase as the root proliferates till about 8th week in both geno-types, only to decrease later. However, consistently, the

estimated values are higher for T₃-29 variety compared to M-27 variety. Since actual SM data for Jorhat for these three years are also available, effectiveness of model to given reasonable estimates of soil moisture was tested by subjecting the three sets of weekly values jointly, as also for these three individual years, to χ^2 analysis. In none of the cases, the χ^2 values were significant at 5% level. Thus, it is concluded that model adopted can give reasonably accurate estimate of soil moisture in mustard for areas where measured SM observations are not available.

Since the results for Jorhat were encouraging, an attempt has also been made to compute and examine pattern of SM for Samakhunta, Raipur and Jodhpur. The results for these stations are depicted in Figs. 2 (a-c). At Samakhunta (Fig. 2a), two irrigations and 2 cm rainfall, mostly occurring during maturity in 1989, gave rise to highest SM. One irrigation in 4th week in 1989 contributed to an initial higher SM compared to 1986. But rainfall in the 1st, 3rd and 10th week and an irrigation in 8th week in 1986 gave somewhat higher SM than in 1988.

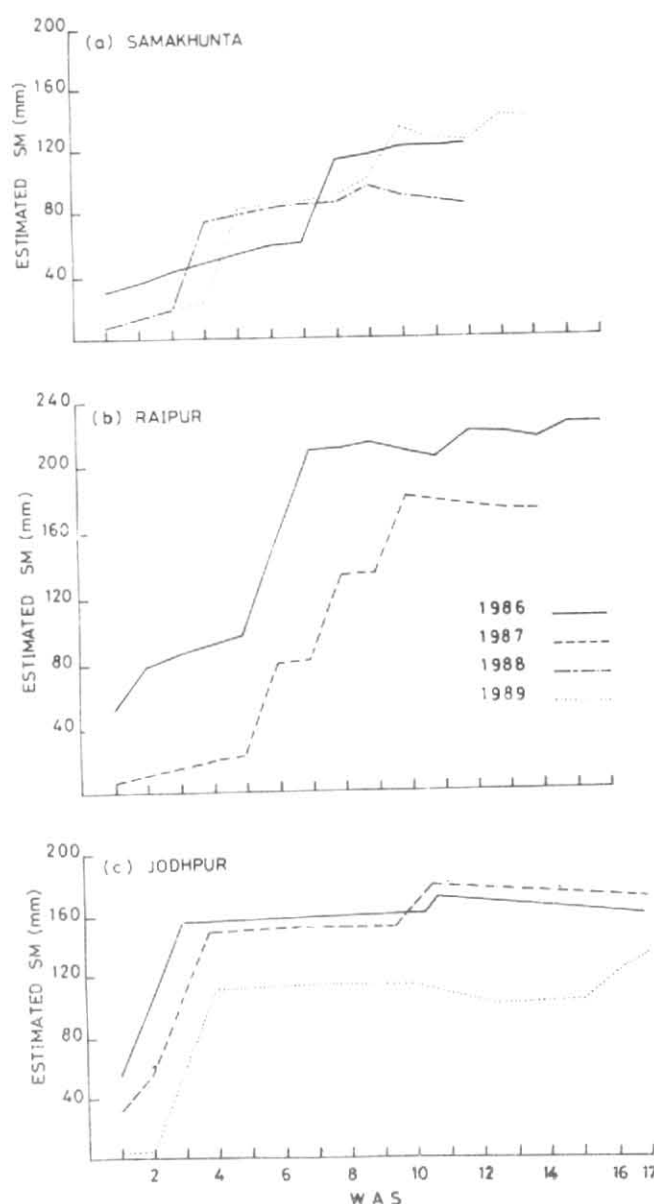
Similarly, though number and timing of irrigation at Raipur for "Varuna" were the same, about 50 mm of well distributed rainfall gave higher SM in 1987 compared to 1988.

The amount of SM used by mustard at Samakhunta and Raipur were comparable. At Jodhpur, the crop was irrigated practically every week in 1986 and 1987. The quantum of SM remained high in both years. In contrast, in 1989, when only two irrigations were applied and inspite of some good rainfall towards the end of the crop season, the SM did not attain the high value as observed in other years (Fig. 2c).

The result emerging from the analysis is that the maximum computed SM is invariably seen 8-10 weeks after sowing, mostly in the 8th week in any climatic type. This period coincides with the flowering phase when the demand of SM by the plant is maximum.

5.3. Soil moisture use in different depths

For want of actual soil moisture data from other stations, soil moisture use in different depths by mustard has been discussed for Jorhat only for 1987, 1988 and 1989. The soil moisture use in both varieties (Table 3) is nearly constant. In general, moisture increased with increase in depth of the soil



Figs. 2 (a-c). Estimated soil moisture

profile. About 5% of water use by mustard was from the upper 0-15 cm soil layer and about 1/5th from 0-30 cm soil profile for both T₃-29 and M-27 varieties. The increase in moisture use pattern with increased soil depth was due to the fact that most of the roots had their spread in deeper layers and only a small fraction remained in top soil profile. The 45 cm layer of M-27 used less water than T₃-29 and this was perhaps due to extensive proliferation of root system in T₃-29 which enabled it to utilize moisture from deeper layers better. It also suggests that the former geno-type probably needs slightly less moisture in top layers.

The SM pattern indicates that inspite of low rainfall, one irrigation in 1987 resulted in more SM

TABLE 3

Soil moisture (mm) pattern at Jorhat

Year	Soil depth				0-60 cm depth (mm)
	0-15 (cm)	15-30 (cm)	30-45 (cm)	45-60 (cm)	
1987	18.4 (5.0)	73.8 (19.0)	123.1 (31.0)	178.6 (45.0)	393.9
1988	18.5 (4.8)	73.1 (19.3)	120.9 (31.8)	167.6 (44.1)	380.1
1989	20.7 (6.5)	57.7 (18.0)	98.9 (30.9)	142.6 (44.6)	319.9

N.B. — Figures in the parenthesis denote percentage of total moisture in 0-60 cm layer.

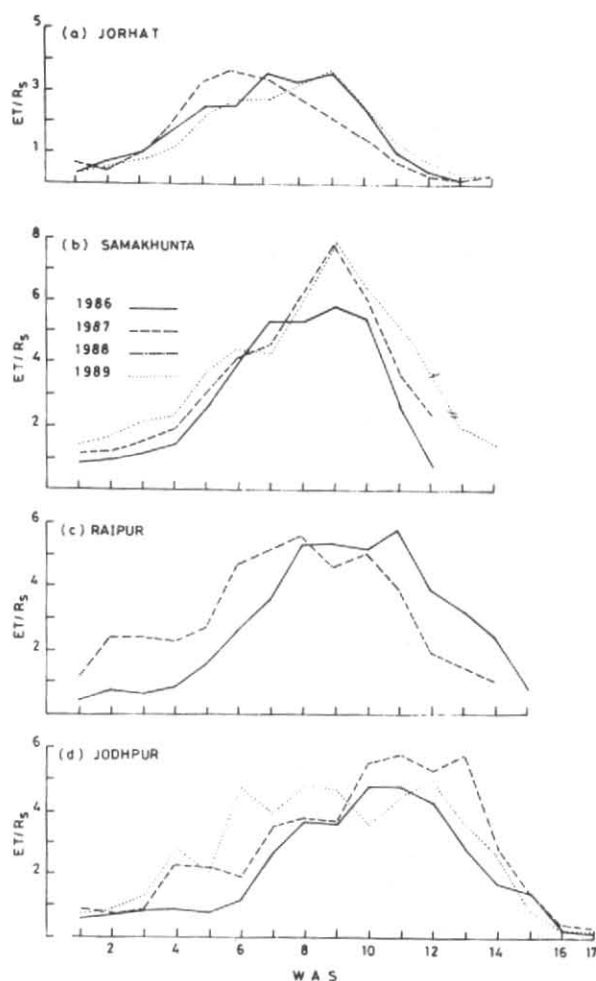
depletion of about 394 mm from entire root-zone of 60 cm depth. This might be due to additive effect of higher transpiration from increased leaf areas and more water loss from soil surface through evaporation. Subdued winter rainfall activity in 1987 also resulted in scarce soil moisture availability in upper layer of soil profile and hence deeper root growth in search of moisture. During 1988, when no irrigation was applied, the crop extracted less moisture from 60 cm depth layer, though the rainfall was nearly double than in 1987. Persistent cloudiness during the crop season in 1989, as reflected in the total seasonal rainfall, perhaps led to lower evaporation and hence lower (*i.e.*, 320 mm) soil moisture depletion in the 60 cm soil profile.

5.4. Evapotranspiration-radiation relationship

The ratio ET/R_s provides an indirect method of estimating ET in case R_s is known. ET/R_s ratio can be used to estimate ET from R_s , which, then, can be used to predict irrigation needs (Carrekar 1963). This ratio also reflects the combined effect of the energy balance components and hence can be utilised to compute the energy balance of crops during different phenological growth phases. For individual stations it is shown in Figs. 3 (a-c).

In the moist environment of Jorhat (Fig. 3a), the ET/R_s values for mustard revealed similar pattern in all the three years, with a maximum of 0.4.

Mustard attains higher ET/R_s values in Samakhunta of about 0.8 in 1988 and 1989 and 0.58 in 1986 (Fig. 3b). These values were realised towards end of growing season, after flowering and could be ascribed to irrigation. For sandy clay loam for cotton, Namken *et al.* (1968) found the maximum ratio ranging from 0.42 to 0.73.



Figs. 3 (a-d). Weekly ET/R_s ratio

Large deviations up to 7 weeks after sowing (WAS) were observed at Raipur (Fig. 3c) but the pattern remained almost identical subsequently. In this case the maximum ratio is of 0.58 in both the years.

Because of irregular availability of moisture to mustard, in the sandy soils of Jodhpur, the pattern in each of the three years revealed much diversification from week-to-week (Fig. 3d) till the commencement of senescence. The rapid decline of ET/R_s ratios after attaining peak indicates reduced transpiration rates as the lack of available water in the root zone begins to limit plant evaporation. The maximum ET/R_s ratio ranged between 0.5 to 0.6.

Leaf area index for field crops is closely associated with the plant height (Chang 1968). In the present study the maximum ET/R_s ratio was generally observed at the time when the plant had reached a maximum height. Increased leaf area and concurrent increase in the percentage of the ground shaded by mustard plant probably explains much of the increase of the ratio during that time. Subsequently, though the plant height remains unaltered, rapid senescence led to reduced plant evaporation and hence ET/R_s ratio.

Mustard ET/R_s values were consistently above 0.4 during the period of maximum water use at all the four locations. The main difference in the maximum ET/R_s ratios of mustard grown in these four varied locations was that the maximum is reached early in the sandy clay loam soil of Jorhat while it is later in the crop season in the other soils, in particular, in the sandy soils of Jodhpur where the maximum is nearer to the end of the crop growth season.

6. Conclusions

The following conclusions could be drawn from the analysis:

- (i) The mustard plant uses maximum water in the non-humid climates.
- (ii) For a crop of 90-95 days duration, maximum use of water occurs at 31-60 days after sowing; for crops of longer duration, it is between 61 to 90 days after sowing.
- (iii) The frequency of irrigation helps substantially to increase the consumptive use in drier environment.
- (iv) The maximum computed soil moisture occurs 8-10 weeks after sowing.
- (v) ET/R_s ratio generally attains a peak between 8-12th week after sowing at Jorhat, around 9th week at Samakhunta, 8-11th week at Raipur and 10-13th week at Jodhpur.

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