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Water use pattern and related agrometeorological indices of rabi & kharif sunflower (*Helianthus annuus* L.) at Deccan plateau

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सार - बंगलौर में फसल की अवस्थाओं का पता लगाने हेतु तुलनात्मक जल उपयोग पैटर्न तथा कृषि मौसम विज्ञान के इंडेक्सों को समझने के लिए रबी और खरीफ दोनों फसलों के मौसमों में उगाई गई सूरजमुखी (1992 और 1993) की आधुनिक किस्मों तथा के.बी.एस.एच.-II (1988-1991 तक) से संबंधित कृषि मौसम विज्ञान के इंडेक्सों और जल उपयोग के आकलन से संबद्ध कृषि मौसम विज्ञान के आंकड़ों का उपयोग किया गया है। इन अध्ययनों से यह पता चला है कि वर्ष 1990 को छोड़कर रबी मौसम की अपेक्षा खरीफ मौसम के लगभग सभी वर्षों में माध्य साप्ताहिक जल का उपयोग अधिक हुआ है तथा पौधों की विकास अवधि में इसके अंतिम अवस्था में पहुँचने पर पौधे की बढ़ोतरी के कारण इसमें प्रयुक्त किए गए जल के उपयोग में वृद्धि हुई है। रबी मौसम की तुलना में खरीफ के मौसम में ए. आर. आई. (कृषि जलवायु वर्षा इंडेक्स) और संचयी वाई.एम.आई. (उपज आर्द्रता इंडेक्स) हमेंशा अधिक रहे हैं तथा इससे पौधे की बढ़ोतरी की भिन्न-भिन्न अवस्थाओं में वायुमंडल में व्याप्त मौसम की स्थितियों के साथ-साथ मृदा की आर्द्रता के दबाव से उत्पन्न हुए वार्षिक और मौसमी परिवर्तनों का पता चला है। ए.आई. (शुष्कता इंडेक्स) के संबंध में, खरीफ मौसम के दौरान पौधे की वृद्धि की आरम्भिक और अंतिम अवस्थाओं में उच्च मानों का पता चला है जिससे पौधे की बढ़ोतरी के समय से लेकर बीज बनने की अवस्था तक पौधों में कम शुष्कता का पता चला है। पौधे की जल उपयोग क्षमता (डल्ब्ल्यू. यू.ई.) से पौधे की भिन्नताओं और ऋतुओं के कारण होने वाले व्यापक परिवर्तनों का भी पता चला है।

ABSTRACT. The agrometeorological data pertinent to estimation of water use and related agrometeorological indices of KBSH - II (1988 to 1991) and MORDEN varieties of sunflower (1992 and 1993) cultivated both in rabi and kharif seasons, were used to understand the comparative water use pattern and agrometeorological indices for getting an idea about the crop condition at Bangalore. The study revealed that mean weekly water use was higher in almost all the years during the kharif season than during the rabi season except in 1990 and the consumptive water use increased with development of the vegetative cover of the crop reaching a peak value in the vegetative growth stage. The ARI (agroclimatic rainfall index) and cumulative YMI (yield moisture index) were always higher during the kharif season than correspondingly those during the rabi season and showed yearly and seasonal variability in different growth stages which was due to the moisture stress condition of the soil as well as prevailing weather conditions of the atmosphere. In case of AI (aridity index), high values were observed at early and late crop growth stages during the kharif season which showed that the crop experienced less aridity between vegetative to seed formation stage. The water use efficiency (WUE) of the crop also revealed wide variation due to variety and season.

Key words – ARI, YMI, AI, WUE, Kharif, Rabi, Vegetative, Seed formation.

1. Introduction

Sunflower is one of the important oilseed crops of India and its edible oil is especially recommended for heart patients. Sunflower can be grown throughout the year because it is a photo and thermoinsensitive crop. It has a deep tap root system that makes it drought tolerant and thrive in low rainfall (250 - 300 mm) during the growing season. The plant can mobilise water from quite deep layers of the soil. It is fairly tolerant to both heat and cold and is grown in a wide range of climate (Putt, 1963) from cold temperature to subtropics with favourable temperatures between 10° C and 42° C (18° C - 25° C as optimum for good growth). Depending on the available season, varieties differ in duration (80 days in cool temperature to 150 days in tropics and subtropics) of total growing period. The crop has low water requirement and is suited to semi arid areas with good retentive soils as well as general farming conditions in traditional farms. In the absence of the rain, two irrigations are sufficient for a successful crop. In areas where the crop is grown during summer, it requires about 380 mm of water. The effect of

TABLE 1

Agrometeorological information of rabi and kharif sunflower

Season	Year	Variety	Date of sowing	Duration (Days)	Total ET use (mm)	Potential evapotrans-piration (mm)	Seasonal rainfall (mm)/ rainy days	Total irrigation amount / frequency from sowing to harvesting (mm/days)	Yield (q/ha)	Water use efficiency (kg/ha/mm)
Rabi	1988	KBSH - II	18 Jan '88	98	251.1	568.4	78 / 05	NIL	7.38	2.94
Kharif	1988	KBSH - II	20 Jul '88	106	353.0	498.1	759 / 36	44 / 02	9.71	2.75
Rabi	1989	KBSH - II	22 Jan '89	107	448.5	647.3	25 / 03	375 / 10	13.61	3.03
Kharif	1989	KBSH - II	15 Jul '89	101	482.0	571.7	593 / 28	46 / 03	10.98	2.28
Rabi	1990	KBSH - II	07 Jan '90	107	412.8	585.1	10 / 01	269 / 10	10.93	2.65
Kharif	1990	KBSH - II	22 Jul '90	90	270.9	478.8	180 / 19	77 / 04	6.97	2.57
Rabi	1991	KBSH - II	06 Jan. '91	90	194.6	517.4	04 / 01	94 / 08	5.29	2.72
Kharif	1991	KBSH - II	21 Jul .'91	98	315.6	434.0	466 / 31	126 / 06	7.89	2.50
Rabi	1992	MORDEN	21 Jan '92	98	329.7	566.3	10 / 03	197 / 10	9.17	2.78
Kharif	1992	MORDEN	22 Jul. '92	92	324.5	457.4	404 / 29	109 / 04	7.61	2.34
Rabi	1993	MORDEN	24 Jan. '93	102	308.6	599.0	06 / 01	139 / 07	9.21	2.98
Kharif	1993	MORDEN	02 Aug 93	87	307.3	367.6	751 / 28	29 / 01	8.65	2.81
			Mean	98	333.2	524.3	274 / 15	137 / 06	8.95	2.69
			S.D.	6.7	78.4	76.6	290 / 14	101 / 03	2.10	0.23
			CV (%)	6.8	23.5	14.6	106 / 93	74 / 54	23.46	8.55

CV - Coefficient of variability , SD - Standard deviation

irrigation schedule on consumptive water use of sunflower was observed by Bhan and Khan (1980) at Kanpur, Jena *et al*., (1982) in West Bengal, Hegde (1988) in Karnataka and Venkanna *et al*. (1994) at Telengana region. Cox and Jalliff (1986) and Unjer (1983) determined the evapotranspiration rates for sunflower in U.S.A. Das *et al*., (1997) also analysed the mean water use per day by the crop during rabi and kharif seasons at Bangalore.

Owing to the wide adaptability and high yield potential among oilseed crops, cultivation of sunflower has recently attracted the attention of farmers, as it is a more remunerative crop and can fit well in the crop rotation. However, meagre information is available on water consumption and agrometeorological indices of the crop in general. In the present study, an attempt has been made to understand the water use pattern as well as agrometeorological indices of sunflower during rabi and kharif season for generating information about the water use pattern and thus enable to take appropriate measures, if any, during critical growth stages of the crop.

2. Materials and methods

The study pertains to Bangalore (12°57' N, 77° 38' E) which has a semi-arid climate. Data of KBSH -II variety for the period 1988 to 1991 and Morden variety of sunflower for 1992 and 1993, cultivated both in the rabi and kharif seasons were used. Both the varieties due to their high yields, high oil contents and wide adaptability are recommended for cultivation throughout India. The plant height and head diameter of Morden variety are 80 cm to 100 cm and 12 cm to 15 cm respectively and these are comparatively higher in case of KBSH-II variety. Irrigation was applied to the crop for survival when needed and the amount of irrigation recorded is furnished in the Table 1. All the meteorological observations had been recorded at the observatory adjoining the experimental field. Daily data on rainfall, the maximum and minimum temperatures, relative humidity, bright hours of sunshine, evaporation and actual evapotranspiration (AET) were collected for six years (1988-93) and the values were used for computation of potential evapotranspiration (PET) by modified Penman method and for evaluation of different agrometeorological indices at various growth stages of the crop.

The crop observation on different phenophases are taken as per criteria given in the publication of WMO (1982). The dates of all phenological observations were collected from the observatory and the actual period (in standard weeks) for each of the critical growth stages (*viz*.,

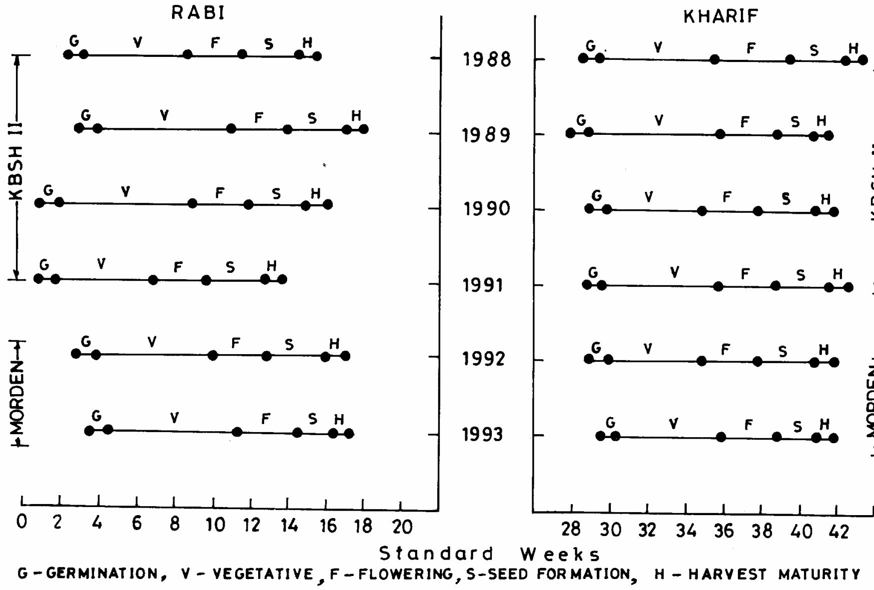

Fig. 1. Growth stages and their duration for sunflower in different years

TABLE 2

Phasewise water use of sunflower (ET)

Season	Year	Germination	Vegetative	Flowering	Seed formation	Harvest maturity	Total ET (mm)	Mean weekly ET (mm)
Rabi	1988	20.2 (8)	107.9 (43)	70.3 (28)	42.5 (17)	10.2 (4)	251.1	17.9
	1989	31.4 (7)	192.8 (43)	130.2 (29)	71.7 (16)	22.4(5)	448.5	29.3
	1990	20.0 (5)	197.8 (48)	111.0 (27)	71.4 (17)	12.6 (3)	412.8	27.0
	1991	17.5 (9)	80.5 (41)	50.4 (26)	38.2 (20)	8.0 (4)	194.6	15.1
	1992	20.3 (6)	143.5 (44)	84.7 (26)	63.7 (19)	17.5 (5)	329.7	23.6
	1993	15.4 (5)	138.3 (45)	103.1 (33)	42.7 (14)	9.1 (3)	308.6	21.2
Mean		20.8 (7)	143.5 (44)	91.6 (28)	55.0 (17)	13.3 (4)	324.2	22.4
S.D.		5.1	42.1	26.4	14.2	5.1	87.3	4.9
Kharif	1988	15.4 (4)	144.2 (41)	95.2 (27)	71.4 (20)	26.8 (8)	353.0	23.3
	1989	21.0 (4)	210.0 (44)	155.4 (32)	60.9 (13)	34.7 (7)	482.0	33.4
	1990	24.5 (9)	112.7 (42)	64.4 (24)	46.2 (17)	23.1 (8)	270.9	21.1
	1991	16.8 (5)	147.7 (47)	86.1 (27)	52.5 (17)	12.5 (4)	315.6	22.5
	1992	13.3 (4)	147.0 (45)	103.6 (32)	39.2 (12)	21.4 (7)	324.5	24.7
	1993	21.0 (7)	149.1 (48)	80.2 (26)	48.6 (16)	8.4 (3)	307.3	24.7
Mean		18.7 (5)	151.8 (45)	97.5 (28)	53.1 (16)	21.2 (6)	342.2	24.9
S.D.		3.8	28.9	28.6	10.5	8.7	67.0	3.9

Note : Figures in the parenthesis represent percentage of the total water use.

germination, vegetative, flowering, seed formation and harvest maturity) of sunflower crop were determined for preparation of yearwise phenological calendar of KBSH-II and Morden variety during the rabi and kharif seasons. These are presented in Fig. 1. Similarly, the existing rainfall, actual and potential evapotranspiration data

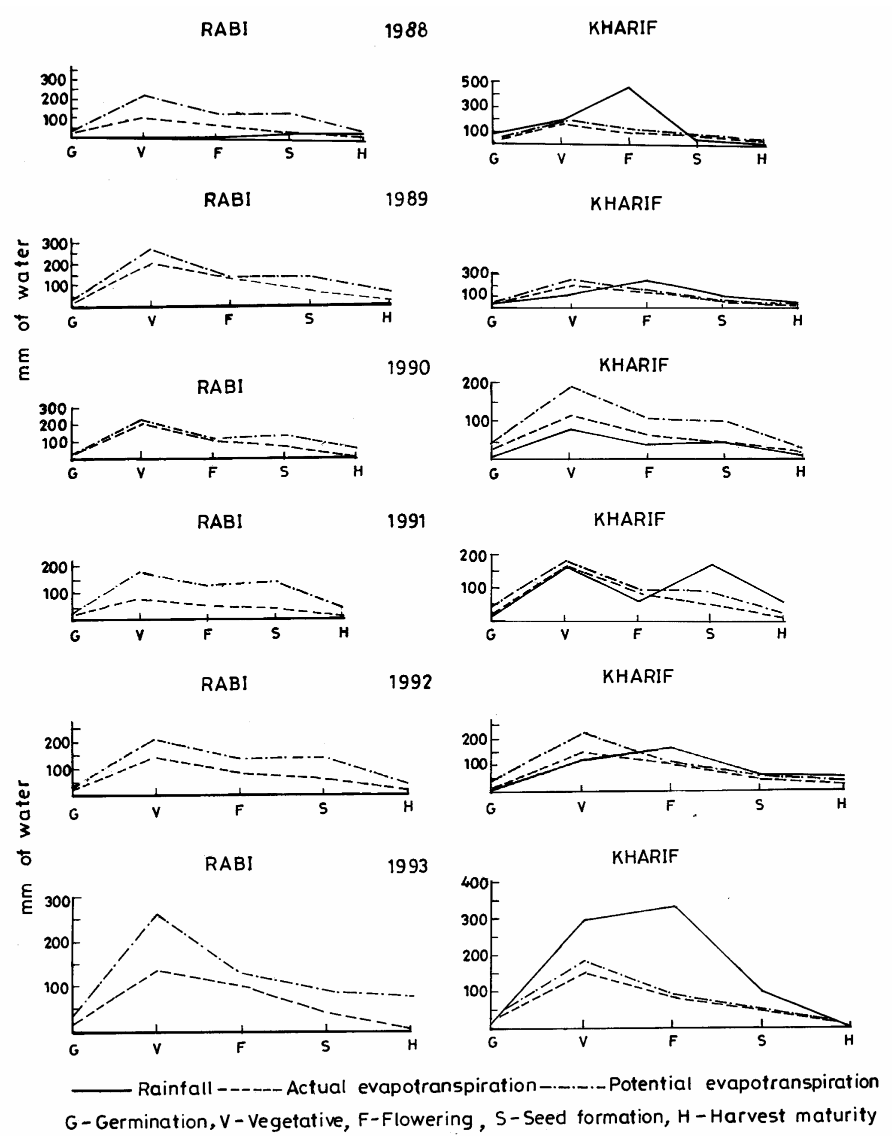

Fig. 2. Rainfall, potential evapotranspiration & actual evapotranspiration at various growth stages of sunflower

available for various growth stages of sunflower for the experimental period 1988-93 of the station are presented in Fig. 2.

The different indices computed are agroclimatic rainfall index, yield moisture index and aridity index. Nieuwolt (1981) proposed agroclimatic rainfall index (ARI) as :

$$\text{ARI} = 100 \times \frac{\text{P}}{\text{PET}} \quad (1)$$

where P and PET are the growthstagewise rainfall (mm) and potential evapotranspiration (mm), respectively as obtained from Fig. 2. The computed values are presented in Table 3.

Yield moisture index (YMI) pertaining to the specific crop under agroclimatic assessment (Steyaert *et al.*, 1981) is defined as :

$$(\text{YMI})_j = \sum_{i=1}^{n} C_{ij} P_i \quad (2)$$

where, $(\text{YMI})_j$ is the yield moisture index for the j th crop. P_i is the rainfall (mm) during the ith crop growth stage and C_{ij} is the appropriate crop coefficient (*i.e.* the ratio of actual to potential evapotranspiration) obtained from Fig. 2. Computed YMI values are presented in Table 4.

TABLE 3

Agroclimatic rainfall index at various growth stages of sunflower

Crop growth stage	Year and season											
	1988		1989		1990		1991		1992		1993	
	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif
Germination	0.0	221.3	0.0	70.6	5.3	12.4	0.0	26.7	0.0	18.6	0.0	58.5
Vegetative	2.0	88.7	2.2	46.3	0.0	42.4	0.0	92.7	0.0	55.8	2.2	162.0
Flowering	6.2	363.1	3.7	160.7	4.8	34.2	2.8	59.5	0.0	153.8	0.0	372.8
Seed formation	25.3	31.2	1.1	173.3	0.6	43.7	0.0	179.2	0.0	115.9	0.4	191.5
Harvest maturity	66.5	0.0	18.3	157.2	3.5	34.8	0.0	217.7	22.6	135.7	0.0	15.0

TABLE 4

Yield moisture index at various growth stages of sunflower

Crop growth stage	Year and season											
	1988		1989		1990		1991		1992		1993	
	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif
Germination	0.0	34.1	0.0	14.8	1.1	3.0	0.0	4.5	0.0	2.5	0.0	12.3
Vegetative	2.1	162.0	4.2	111.9	1.1	50.8	0.0	141.4	0.0	84.5	3.0	253.9
Flowering	6.5	507.7	9.1	361.6	6.4	72.9	1.4	192.7	0.0	243.8	3.0	552.8
Seed formation	17.3	529.9	9.9	467.1	6.8	93.1	1.4	286.8	0.0	289.3	3.2	645.9
Harvest maturity	24.1	529.9	14.0	521.6	7.2	101.1	1.4	314.0	3.9	318.3	3.2	647.2

TABLE 5

Aridity index at various growth stages of sunflower

Crop growth stage	Year and season											
	1988		1989		1990		1991		1992		1993	
	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif
Germination	27.9	56.8	30.5	43.4	24.8	41.7	43.2	60.6	35.6	71.2	54.2	30.2
Vegetative	52.1	30.4	25.9	19.8	15.4	40.8	54.7	16.6	32.6	31.4	47.3	19.0
Flowering	45.5	26.1	6.5	5.1	8.9	41.0	60.4	10.2	38.6	2.6	22.1	10.5
Seed formation	69.9	22.7	48.5	9.6	48.7	55.1	72.7	45.5	54.7	27.3	53.8	6.2
Harvest maturity	77.2	21.2	65.8	16.6	80.2	33.0	80.7	33.7	59.7	41.7	88.4	30.0

Aridity index (AI) as proposed by Thornthwaite (1948) is based on the value of water deficiency at various growth stages and is computed by the formula:

$$\mathrm{AI} = \frac{\mathrm{PET} - \mathrm{AET}}{\mathrm{PET}} \times 100 \qquad (3)$$

where, PET and AET are the potential and actual evapotranspiration (mm), respectively, at various growth stages as obtained from Fig. 2. The AI values are summarized in Table 5.

Correlation coefficient between AI and ARI was worked out seperately for rabi and kharif seasons of all the years and *t*-test was done for indicating the test of significance.

3. Results and discussion

3.1. *Water use of sunflower during rabi and kharif season*

Agrometeorological information including the growing season, rainfall, total water use and water use efficiency (WUE) etc. are given in Table 1. Year-to-year variability in consumptive use of water is generally observed which probably stems from the basic variability inherent in monsoon and non monsoon rainfall. It is observed that total water use of the rabi season crop generally exceeds the total seasonal rainfall whereas the total water use of the kharif season crop is lower than the total seasonal rainfall in all the years except in 1990. This indicates that excess water was available to the crop during the rabi season over and above its evapotranspiration demands through extraction of the soil moisture from root zone depth out of water received through irrigation or rainfall. During the rabi season, the lowest amount of water *i.e*., 194.6 mm was consumed in 1991 whereas in 1989, the crop used the maximum amount of water *i.e*., 448.5 mm. This may be attributed to the rainfall and crop growing period. Similar relationship between rainfall and water use was found during the kharif season where the value ranged from 482 mm in 1989 to 270.9 mm in 1990. The mean water used by sunflower during the rabi and kharif seasons at Bangalore was 324.2 mm and 342.2 mm respectively (Table 2). It is also observed that the water use in MORDEN variety varied from 307.3 mm to 329.7 mm whereas it varied from 194.6 mm to 482 mm in KBSH - II. The consumptive water use by EC- 68414 variety of sunflower at Navasari in south Gujarat varied from 216.8 mm to 345 mm (Chaudhari and Patel 1994) and in semi arid in the northern plains (Hissar), the seasonal water use was 358.5 mm for MSFH - 8 and 311.0 mm for EC - 68415 variety of sunflower (Raj *et al*., 1999).

Ignoring the crop species and season, it appears possible to raise sunflower crop in 98 days at Bangalore and the mean consumptive water use there is about 333.2 mm which is higher than the mean seasonal rainfall but markedly lower than mean evapotranspirational demand of the atmosphere. The variability in the consumptive water use is also low, *i. e*. 23.5 % (Table 1).

Analysis of phasewise water use of sunflower (Table 2) and its contribution to total water use revealed that mean water use in vegetative stage was 143.5 mm during the rabi and 151.8 mm during the kharif season *i. e*. about 44% - 45% of the seasonal water use. The water use between flowering to seed formation stage has varied markedly due to crop season, variation in duration of growth period, microclimatic conditions and cultivars used. The mean water use in the flowering stage varied from 97.5 mm during the kharif season to 91.6 mm during the rabi season and was followed by 55.0 mm and 53.1 mm respectively during the rabi and kharif seasons in the seed formation stage. It was observed that the mean weekly ET use was 22.4 mm during the rabi season and 24.9 mm during the kharif season.

3.2. *Agrometeorological indices*

The computed agrometeorological indices *viz*., ARI, YMI and AI, which represent the relationships between the climate and agricultural production are discussed below.

3.2.1. *Agroclimatic rainfall index (ARI)*

Kharif season rainfall was sufficient to meet the PET demand at various growth stages in all the years except in 1990, whereas the rabi season rainfall in all the years was far less to meet the PET demand at various growth stages of the crop. Hence, ARI values were always less than 100% in all the years during the rabi season (Table 3). Low ARI values were recorded during the rabi season of 1991 and they ranged between 0 - 2.8 %, whereas their range was still narrow (0-2.2%) in 1993 for various growth stages. In general, ARI value recorded during the various growth stages in the kharif season were medium to very high in all the years due to more rainfall received. The ARI values during the kharif season were comparatively higher between vegetative to seed formation stage in most of the years. The values were markedly high in the flowering stage of 1988, 1993 and the harvest maturity stage of 1991.

3.2.2. *Yield moisture index (YMI)*

The cumulative YMI was always lower during the rabi season than that in the kharif season (Table 4). During the rabi season, it was as low as 1.4 in 1991 and had the maximum value of 24.1 in 1988. During the kharif season, cumulative YMI value was maximum and had the value of 647.2 in 1993 and was minimum with the value of 101.1 in 1990. During the kharif season, the cumulative YMI values showed an increasing trend, in all the growth stages from 1989 to 1993 and the same trend was observed upto seed formation stage in 1988. The contribution of individual growth stagewise YMI towards cumulative YMI during the kharif season was high between germination to flowering stage for all the years except what was comparatively low in 1990 which was reflected in poor crop yield. The relationship between YMI and yield for the rabi and kharif seasons have been depicted separately during critical growth stages of vegetative and flowering in Fig. 3. Prasad and Datar (1990) have suggested that YMI is a good drought indicator.

3.2.3. *Aridity index (AI)*

The AI values at various growth stages during the rabi and kharif seasons for different years are shown in Table 5. Differences in AI for all the phenological

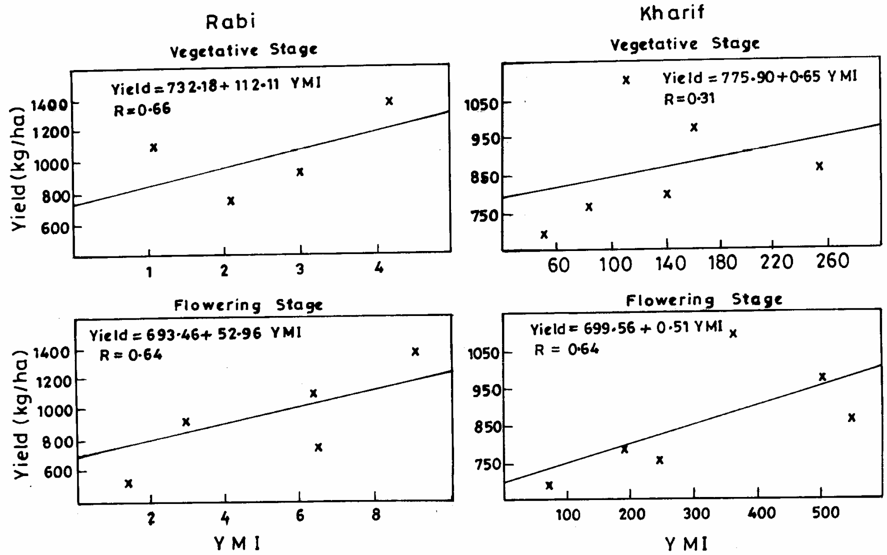

Fig. 3. Relation between yield and YMI of the vegetative and the flowering stages during the Rabi and the Kharif seasons

stages are evident in different years and are ascribed dissimilar pattern of prevailing weather during various crop season, variation in the duration of growth period and microclimatic conditions. In general, AI of the kharif season was higher than that of the rabi season at early crop growth stages but as the season advanced, the value gradually decreased and afterwards the value again increased in the late season except in 1988 and 1993 where the value decreased gradually respectively from sowing to harvesting and sowing to seed formation stage. The flowering stage of the crop experienced mild aridity during both the rabi and kharif seasons of 1989, 1990 and during the kharif season of each of the years 1991 to 1993. In case of seed formation stage , it was mild arid during the kharif season of 1989 and 1993.

The study of correlation coefficients between AI and ARI for all the phenological phases revealed that the relation was negative in the rabi seasons of 1990, 1991, 1993 and the kharif seasons of 1989, 1992 and 1993. The kharif season of 1993 recorded the highest correlation coefficient (–0.81) which was significant at 1% level of significance and was followed by the kharif season of 1992 where the value was –0.78.

The correlation coefficients between the crop yield and agrometeorological indices for all the phenological stages were also worked out seperately for the rabi and kharif seasons. The correlation between crop yield and ARI was positive and maximum (0.59) in the germination stage during the kharif season. The crop yield showed positive correlation with the YMI in all the growth stages during both the seasons. The highest value of correlation coefficients (0.66) in case of rabi season was found during the vegetative stage (Fig. 3). Correlation analysis further illustrated that AI had high negative association with crop yield in the flowering (–0.94) and seed formation stage (–0.90) during the rabi season. All these values of correlation coefficients were significant at 5 % level.

3.3. *Water use efficiency*

The ratio of crop yield to evapotranspiration known as water use efficiency (WUE), serves as a very useful tool in crop and variety selection for maximum yield per unit of water consumed. The WUE is thus given by

$$WUE = Y/ET \quad (4)$$

where, Y = yield of crop

ET = cumulative evapotranspiration during the growth period.

The WUE of sunflower for the rabi season at Bangalore was varied from 2.65 kg/ha/mm in 1990 to 3.03 kg/ha/mm in 1989 and that for the kharif season, varied from 2.28 kg/ha/mm in 1989 to 2.81 kg/ha/mm in 1993 (Table 1). Singh *et al*. (1995) found the WUE of 2.83 kg/ha/mm when four irrigations were applied and the same was 1.79 kg/ha/mm under rainfed condition at western Rajasthan. Choudhari and Patel (1994) also found the WUE in the order of 2.59 kg/ha/mm to 3.10 kg/ha/mm at Navasari (south Gujarat).

4. Conclusion

(*i*) The average water use by sunflower during the kharif season was slightly higher than that during the rabi season and the mean weekly water use was also higher in almost all the years during the kharif season than that during the rabi season except in 1990.

(*ii*) The consumptive use of water increased with the development of the vegetative cover of sunflower reaching peak value in the vegetative growth phase.

(*iii*) The ARI value during kharif season was always higher than that during the rabi season. This value was comparatively higher between vegetative to seed formation stage during the kharif season of most of the years.

(*iv*) The cumulative YMI was always higher during the kharif season than that during the rabi season and showed an increasing trend at various growth stages of the crop from 1989 to 1993.

(*v*) In general, AI of the kharif season was higher than that of the rabi season during the early crop growth stages. With the advancement of the season, the severity aridity gradually decreased and afterwards, it again increased in the late season.

(*vi*) The WUE of sunflower crop revealed wide variation due to variety and season.

(*vii*) The kharif seasons of 1993 and 1992 recorded respectively the maximum correlation of −0.81 and −0.78, significant at 1% level of significance, between AI and ARI.

(*viii*) The correlation coefficients between the crop yield and AI showed high negative values in the flowering (−0.94) and seed formation stage (−0.90) during the rabi season which were significant at 5 % level.

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