Review Article

Performance of safflower varieties under different sowing dates and crop-weather relationships

ABSTRACT

A field experiment was conducted during *Rabi* 2022 at the Zonal Agriculture and Horticulture Research Station, Hiriyur, Chitradurga. The experiment site is situated at 13^0 57**'** 32**"** North latitude and 70^0 37**'** 38**"** East longitude with an altitude of 606.1 m above the mean sea level. The experiment was laid out in split plot design and consist of four sowing windows - 7^{th} October, 21^{st} October, 4^{th} November and 18^{th} November and three varieties of safflower - PBNS-86, Annigeri-1 and A-300 replicated thrice. The results revealed that crops sown on 21^{st} October recorded significantly higher seed yield of 1298 kg ha^{-1} with a variety of PBNS-86 producing significantly higher seed yield of 1233 kg ha^{-1} and it was statistically on par with crop sown on 7^{th} October (1223 kg ha^{-1}). Among the varieties, PBNS-86 produced significantly higher seed yield (1233 kg ha^{-1}). However, it was statistically on par with Annigeri-1 (1197 kg ha^{-1}). The interaction effect was found non-significant. Seed yield had significant positive correlation with weather parameters such as maximum relative humidity (r = 0.485**), minimum relative humidity (r = 0.554**), cumulative bright sunshine hours (r = 0.355*), from flowering to capitulum and seed development stage. The linear regression values show the variation in grain yield was primarily affected by average minimum temperature at 56% followed by average maximum relative humidity at 54% and diurnal temperature range at 50%. During sowing to physiological maturity and lower variations was observed in cumulative pan evaporation at 23% during flowering to physiological maturity. From the study it can be inferred that sowing safflower on 21^{st} October with PBNS-86 variety can be a better option to get higher productivity in central dry zone of Karnataka.

Keywords: Crop weather; evaporation; seed yield; safflower; solar radiation

1. INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is an essential oilseed crop that belongs to the Compositae or Asteraceae family. Safflower is a multipurpose crop with unexploited potential and has worldwide adaptability. Major producers of safflower are India, the United States, Mexico, Kazakhstan, Argentina, China, Ethiopia and Australia . It is one of the important *rabi* oil seed crops mainly grown in semi-arid regions of India, cultivated in vertisols under residual moisture in recent years, especially with increasing interest in the production of biofuels and its well adaptation to saline and drought stress conditions due to its tap strong root .

The productivity of all oil seed crops in India is low except for castor; the area of safflower is grown on 0.64 million hectares in India, with an annual production of 0.45 million tonnes and a productivity of 694 kg ha^{-1} is still very low due to various biotic and abiotic stresses and multitude of other factors. Karnataka is currently the leading state in the country, with an area of 29,000 ha, a production of 19,285 tonnes, and a productivity of 665 kg ha^{-1} (Anon, 2021).

The most essential parameters in safflower production are soil, ambient temperature and soil moisture. As a result, the sowing date becomes more critical. Different sowing dates expose the crop to different ranges of temperature and relative humidity (above and below the crop). Any delay in sowing results in a significant drop in seed yield and oil content. It is critical to sow or plant the crop at the proper time. Early sowing with enhanced varieties could be one of the most cost-effective strategies to boost crop yields.

Safflower demands cool weather throughout the vegetative growth and warm weather during flowering and seed development. An average ambient temperature of 15-16°C is required for seed germination . The seedlings are tolerant to low temperatures and dry weather . The air temperature should be between 20 and 29°C for flowering and seed production.

Warm and humid weather is detrimental to the growth of the safflower plant. High temperatures during flowering harm the floral buds, whereas extremely low temperatures (0°C) cause sterility. Frost is hazardous to plants at the vegetative and reproductive phases of the plants. This crop is not ideal for high altitudes of more than 1000 m, with very cold temperatures and considerable rains. Seeds shrink due to high temperatures during flowering. High humidity promotes disease propagation, especially during the flowering and grain-filling periods (Anon, 2010).

Quantification of these effects may help in the choice of sowing time and match phenology of crop in a specific environment to achieve higher grain yield. Safflower is predominantly grown under *Rabi* season where the present investigation has been carried out which comes under central dry zone of Karnataka, Hence, there is a need to study the influence of different weather parameters on the performance of safflower grown under different environments as affected by change in the sowing dates as well as identifying the suitable varieties of contrasting duration to realise the higher yield of safflower. Key planting factors influencing safflower productions are sowing date and cultivars. Different genotypes may behave differently under similar environmental conditions. With this backdrop considering all the above points, a study on crop-weather relationships of safflower was carried out at the Zonal Agricultural and Horticultural Research Station Babbur Farm, Hiriyur, Karnataka.

2. MATERIAL AND METHODS

2.1 Experimental Site

A field experiment was conducted to understand the performance of safflower varieties under different dates of sowing and crop-weather relationships at Zonal Agricultural and Horticultural Research Station (ZAHRS), Babbur Farm, Hiriyur, which is situated in the Central Dry Zone (Zone-4) of

Chitradurga, Karnataka during rabi season 2022 which is situated at 13^0 57' 32" North latitude and 70^0 37' 38" East longitude with an altitude of 606.1 m above the mean sea level. The soil of the experimental site was slightly alkaline with pH 8.15, low in soil organic carbon (0.37%), low available N (256 kg/ha), medium in available P_2O_5 (34 kg/ha) and medium in soil available K_2O (314 kg/ha). The experiment was laid out in split plot design and consist of four dates sowing (7th October, 21st October, 4th November and 18th November) and three varieties (PBNS-86, Annigeri-1 and A-300) replicated thrice.

2.2 Plant protection measures

The recommended dose of manure (5 t FYM ha^{-1}) was applied 15 days before sowing and incorporated into the soil. The recommended amount of fertilizer (40:40:12.5 kg NPK ha^{-1}) for each treatment was applied in the form of urea, SSP and MOP fertilizers. A basal dose of fertilizers (50% N and 100% P and K) were applied at the time of sowing and the remaining 50% of N was applied in two splits at 30 and 60 days after sowing. Hand weeding and inter-cultivation at 30 DAS were carried out to keep the plots free from weed competition.

2.3 Weather parameters prevailed during the study period

The actual weather during the cropping period *i.e.*, from October to March in the years 2022 and 2023, the highest rainfall was received during October (107.8 mm) and the lowest in December (36.0 mm). The highest mean maximum air temperature was recorded in March (34.7 ºC) and the lowest mean minimum air temperature in January (10.7 ºC). The higher relative humidity was recorded in the month of November (76.75 %) and lower was observed in March (52.7%).

2.4 Data Collection and Statistical Analysis

Growth observations are recorded at 30-day intervals and yield parameters like number of capitulum per plant, weight of capitulum per plant, number of seeds per capitulum and 100 seed test weight were recorded at harvest. The data on rainfall, temperature, relative humidity, sunshine hours, solar radiation and evaporation were obtained from the agro-meteorological observatory located in the study area. The correlation coefficient was worked out between prevailed weather parameters at and different phenophases with seed yield of safflower. Regression analysis was carried out by considering those weather parameters, which significantly influenced crop growth, yield and yield attributes were entered in this analysis to derive prediction models separately. However, the best-suited regression equations are elaborated in this paper.

3. RESULTS AND DISCUSSION

Weather factors that prevailed during different phenophases of safflower, sown under staggered dates, influenced the crop's final yield through their influence on different growth and yield attributes. The critical agrometeorological variables associated with agricultural production are rainfall, air temperature, relative humidity and solar radiation. By relating and comparing the agro-climatological requirements of the crop with the existing agro-climatic conditions in an area, one can find the extent to which the needs are satisfied during the different phases of the crop growth and development.

3.1 Influence of Weather Parameters at Different Stages of Crop Growth

Weather prevailed during different crop phenophases were significantly influenced by yield and yield attributes (Tables 1 and 2). Weather parameters such as maximum relative humidity (r = 0.485**), minimum relative humidity (r = 0.554**), cumulative bright sunshine hours (r = 0.355*), from flowering to capitulum and seed development stage had significantly positive relationship with seed yield. In case of maximum temperature from sowing to emergence (r = 0.599**), minimum temperature from sowing to emergence and emergence to rosette stage (r = 0.632** and r = 0.471**) had significantly positive relationship with seed yield. cumulative solar radiation from emergence to rosette stage (r = 0.444**), had significantly positive relationship with seed yield. Environmental changes associated with different sowing dates (relative humidity, sunshine, temperature) have a modifying effect on safflower plant growth and development. Each variety has an optimum sowing date and the greater the deviation from this optimum (early or late sowing), the greater the yield loss. These findings are in line with Adesh et al. (2020), Shabana *et al*. (2013), Anil *et al*. (2008) and Sawan (2017).

3.2 Seed Yield (Kg ha^{-1}), Stover Yield (Kg ha^{-1}), Biological yield (kg ha^{-1}) and Harvest Index of safflower as influenced by dates of sowing and varieties.

The data on seed yield of safflower varieties as influenced by dates of sowing are presented in Table 4. Seed yield produced significantly higher in crop sown on October 21st (1298 kg ha^{-1}), and it was statistically on par with crop sown on October 7th (1223 kg ha^{-1}). However, lower seed yield was recorded on November 18th (1020 kg ha^{-1}) sowing. Among the varieties, PBNS-86 recorded a significantly higher seed yield (1233 kg ha^{-1}), and it was on par with Annigeri-1 (1197 kg ha^{-1}). Significantly lower seed yield was recorded in variety A-300 (1040 kg ha^{-1}). Similar results were also observed in the earlier study conducted by Barla *et al*. (2020) and Sahu *et al*. (2017), and they reported that seed yield is directly related to plant growth duration since in long plant growth duration, the rate of radiation absorbed by plant increases and therefore, seed yield is enhanced. Haulm yield

Treatment	Growth stage	Period (days)	Cum RF (mm)	Avg Tmax (^{0}C)	Avg Tmin (^{0}C)	C BSSH (hrs)	C SR (MJm^{-2})	RH I (%)	RH II (%)	EVP (mm)	WS ($Km\ hr^{-1}$)	DTR (^{0}C)
7th October + Annigeri-1	P1	9.0	90.0	28.3	20.2	37.0	99.9	85.5	71.2	27.6	0.5	8.1
	P2	17.0	19.4	28.6	19.8	128.8	255.6	80.0	71.7	63.2	0.6	8.8
	P3	17.0	42.6	27.9	20.7	108.6	209.6	84.8	67.9	56.4	0.6	10.5
	P4	23.0	27.6	28.7	15.8	132.6	245.3	82.0	63.2	74.5	0.6	12.8
	P5	19.6	10.4	27.8	14.5	141.5	234.1	80.2	48.4	58.7	0.8	13.3
	P6	25.6	0.0	29.2	10.6	223.3	364.9	76.9	38.4	75.8	0.6	18.6
	P7	19.6	0.0	31.2	11.6	176.5	315.9	77.4	35.6	66.4	0.9	19.6
7th October + PBNS-86	P1	8.3	89.4	28.3	20.2	31.9	89.4	85.0	71.1	26.2	0.6	8.0
	P2	16.3	8.4	28.7	20.1	127.1	251.1	80.8	71.0	59.2	0.6	8.6
	P3	16.6	42.6	27.7	17.5	103.7	204.8	84.0	69.3	55.6	0.9	10.2
	P4	22.0	6.2	28.7	15.8	136.8	245.9	83.0	62.5	74.7	0.6	12.9
	P5	19.6	36.0	27.7	14.3	124.9	217.2	79.9	52.2	55.1	0.8	13.4
	P6	25.6	0.0	29.2	11.0	225.6	365.1	77.4	38.9	77.3	0.6	18.1
	P7	19.3	0.0	30.7	11.7	168.4	300.4	76.7	36.5	63.2	0.9	19.0
7th October + A-300	P1	10.3	90.0	28.3	20.3	45.9	119.1	84.7	70.5	31.2	0.5	8.0
	P2	17.6	47.1	28.5	19.3	128.0	256.0	80.4	72.5	65.6	0.7	9.1
	P3	17.0	1.0	28.0	16.8	116.6	217.7	84.9	67.2	58.2	0.8	11.1
	P4	23.0	42.2	28.8	16.3	117.6	226.5	82.4	63.7	68.4	0.7	12.5
	P5	20.3	0.0	27.9	14.0	165.0	263.5	78.9	45.1	66.4	0.7	13.8
	P6	26.0	0.0	29.3	10.4	224.0	371.0	77.1	37.5	76.4	0.6	18.9
	P7	19.6	0.0	31.6	11.5	182.6	328.7	76.4	35.7	68.5	1.0	20.0
21st October + Annigeri-1	P1	8.3	0.0	28.8	20.4	74.1	139.5	79.7	71.1	33.4	0.7	8.4
	P2	17.0	42.6	27.7	17.6	103.6	207.1	82.9	70.3	57.6	0.9	10.0
	P3	16.3	6.2	28.3	16.3	103.0	188.6	84.8	65.7	55.5	0.5	12.0
	P4	22.6	36.0	28.1	14.7	135.2	239.9	79.5	56.3	66.2	0.8	13.3
	P5	19.6	0.0	29.0	12.5	166.8	266.5	78.1	40.2	62.0	0.7	16.5
	P6	25.3	0.0	29.9	10.7	221.2	379.1	76.8	36.9	77.1	0.7	19.1
	P7	18.6	0.0	32.5	11.4	188.1	345.4	73.8	32.6	76.8	1.0	21.1
21st October + PBNS-86	P1	7.3	0.0	28.8	20.6	66.8	125.1	79.9	70.5	29.5	0.6	8.1
	P2	16.3	42.6	27.8	17.5	105.2	207.4	82.2	70.5	56.5	0.9	10.3
	P3	16.6	6.2	28.0	16.6	99.7	187.1	85.2	66.3	56.0	0.4	11.4

	P4	21.0	36.0	28.4	15.1	120.8	217.8	79.7	58.3	60.9	0.8	13.2
	P5	19.6	0.0	28.7	13.0	164.6	262.6	78.8	41.5	63.9	0.7	15.7
	P6	25.6	0.0	29.6	10.4	223.7	379.0	76.6	36.9	76.3	0.7	19.1
	P7	20.3	0.0	32.3	11.4	200.8	367.6	74.1	33.7	79.6	1.0	20.9
21st October + A-300	P1	9.6	0.0	28.7	20.2	81.3	155.2	79.4	71.2	38.4	0.7	8.5
	P2	17.3	42.6	27.7	17.6	107.3	211.8	83.5	69.7	58.2	0.9	10.1
	P3	17.0	6.2	28.4	15.9	109.0	196.8	84.5	65.0	58.2	0.4	12.5
	P4	22.3	36.0	28.1	14.3	136.2	239.0	79.5	53.7	64.4	0.9	13.7
	P5	20.3	0.0	29.0	12.1	174.3	279.2	77.8	40.4	62.7	0.7	16.9
	P6	25.6	0.0	30.2	11.1	223.2	388.3	76.9	37.0	80.4	0.8	19.1
	P7	19.6	0.0	32.8	11.2	200.7	373.4	71.2	30.3	83.6	1.2	21.6
4th November + Annigeri-1	P1	8.3	1.0	28.2	17.5	67.6	122.0	84.0	65.3	28.7	0.8	10.7
	P2	16.6	6.2	27.9	16.9	93.4	180.3	85.9	67.4	55.1	0.6	11.0
	P3	16.6	36.0	29.2	15.7	80.3	157.5	81.0	62.2	47.0	0.6	13.4
	P4	21.6	0.0	28.0	13.5	178.5	290.0	78.4	43.3	72.2	0.7	14.4
	P5	19.3	0.0	29.1	9.7	169.2	278.3	76.5	37.7	54.5	0.6	19.3
	P6	25.0	0.0	31.4	11.5	227.8	412.2	76.3	35.4	87.8	0.9	19.8
	P7	19.3	0.0	33.5	11.5	188.8	369.7	66.5	28.6	90.8	1.5	22.0
4th November + PBNS-86	P1	7.3	1.0	28.3	17.3	61.5	110.1	83.8	64.3	25.2	0.8	10.9
	P2	16.3	6.2	27.8	17.0	89.0	174.7	86.3	67.9	53.8	0.7	10.7
	P3	16.6	35.0	29.2	15.7	86.6	164.1	80.6	62.6	48.6	0.8	13.4
	P4	20.6	0.0	27.9	13.9	168.2	268.6	79.1	44.8	67.6	0.7	13.9
	P5	19.3	0.0	29.1	9.9	168.5	275.2	79.8	38.1	55.4	0.6	19.1
	P6	25.3	0.0	31.1	11.6	229.0	409.2	76.4	35.7	86.4	0.9	19.5
	P7	19.3	0.0	33.3	11.3	190.8	370.4	66.6	28.7	89.1	1.5	22.0
4th November + A-300	P1	9.3	1.0	28.0	17.7	68.4	127.2	84.6	66.8	31.4	0.9	10.3
	P2	17.3	6.2	28.0	16.6	103.5	194.3	85.2	66.2	58.0	0.6	11.3
	P3	16.3	36.0	29.0	15.6	81.7	156.0	80.8	61.0	45.2	0.9	13.3
	P4	22.3	0.0	28.2	13.2	188.1	298.4	78.4	42.6	74.1	0.7	14.9
	P5	20.3	0.0	29.3	10.1	175.6	292.6	76.7	37.5	58.6	0.6	19.2
	P6	24.6	0.0	31.7	11.4	234.6	423.8	75.2	34.9	89.7	1.0	20.3
	P7	18.6	0.0	33.6	11.9	174.6	350.8	65.7	29.1	89.5	1.6	21.7
18th November	P1	8.3	6.2	27.8	15.7	46.2	89.3	86.8	68.8	27.4	0.5	12.0
	P2	16.6	34.9	29.2	15.7	94.4	173.7	80.1	61.8	51.6	0.7	13.5

+ Annigeri-1	P3	16.6	1.4	27.5	14.0	114.6	200.9	79.8	47.8	51.2	0.8	13.5
	P4	20.6	0.0	29.2	10.9	179.3	293.9	78.2	38.8	61.9	0.6	18.2
	P5	19.3	0.0	30.1	11.4	166.2	289.7	76.1	37.3	60.5	0.8	18.7
	P6	25.6	0.0	32.9	11.3	251.7	480.6	71.5	30.0	108.7	1.2	21.6
	P7	18.6	0.0	34.2	11.6	160.1	334.5	64.7	35.6	102.0	1.3	18.0
18th November + PBNS-86	P1	7.3	6.2	27.7	15.2	42.0	80.3	86.1	70.6	24.7	0.5	12.4
	P2	16.3	29.6	29.1	15.7	98.5	177.4	79.9	60.2	53.8	0.7	13.3
	P3	16.6	6.3	27.6	14.1	110.5	187.5	80.7	50.2	46.8	0.8	13.3
	P4	20.6	0.0	29.1	11.4	183.1	292.1	77.9	39.6	62.9	0.6	16.7
	P5	18.6	0.0	29.9	11.2	160.1	277.6	76.2	36.8	57.7	0.8	18.9
	P6	25.6	0.0	32.7	7.9	256.2	475.9	72.4	31.2	105.9	1.1	20.9
	P7	18.6	0.0	34.1	14.6	153.8	334.3	64.3	34.3	99.4	1.4	20.6
18th November + A-300	P1	9.3	6.2	28.0	15.8	54.8	103.3	86.5	67.3	31.2	0.5	12.1
	P2	17.3	36,0	29.2	15.8	89.4	170.0	80.4	62.6	50.4	0.8	13.3
	P3	16.3	1.0	27.4	13.7	131.4	210.0	79.2	45.4	53.4	0.7	13.6
	P4	21.3	0.0	29.2	10.5	189.2	304.6	77.7	38.3	63.0	0.6	18.6
	P5	20.3	0.0	30.5	11.7	174.0	308.3	76.5	37.0	63.3	0.8	18.8
	P6	24.6	0.0	33.0	7.7	246.7	467.5	70.6	29.7	102.3	1.3	21.8
	P7	18.6	0.0	34.5	16.3	152.0	337.2	46.6	36.6	99.0	1.2	18.1

Table: 1. Weather parameters prevailed at different crop growth stages of safflower during the experimental period

Table: 2. Correlation between seed yield and weather parameters at different phenophases of safflower

	P_1	P_2	P_3	P_4	P_5	P_6	P_7
Cumulative rainfall	-	0.067^{NS}	0.212^{NS}	-	-	-	-
Average maximum temperature	0.599**	-0.335*	-0.052^{NS}	-0.245^{NS}	-0.476**	-0.599**	-0.536**
Average minimum temperature	0.632**	0.471**	0.597**	0.530**	0.471**	-0.407*	-0.409*
Cumulative bright sunshine hours	0.032^{NS}	0.388*	-0.089^{NS}	-0.551**	-0.363*	-0.312^{NS}	0.355*
Cumulative solar radiation	0.165^{NS}	0.444**	0.097^{NS}	-0.563**	-0.513**	-0.479**	-0.040^{NS}

Maximum relative humidity	-0.475**	-0.045^{NS}	0.594**	0.398*	0.635**	0.485**	0.549**
Minimum relative humidity	0.412*	0.532**	0.556**	0.583**	0.473**	0.554**	0.130^{NS}
Wind speed	-0.040^{NS}	0.199^{NS}	-0.379*	0.260^{NS}	0.062^{NS}	-0.574**	-0.498**
Pan evaporation	0.025^{NS}	0.326^{NS}	0.179^{NS}	0.111^{NS}	0.037^{NS}	-0.463**	-0.465**
Diurnal temperature range	-0.613**	-0.530**	-0.603**	-0.484**	-0.516**	-0.533**	0.037^{NS}

*- Significant @ 5%, **- Significant @ 1%

Where,

P_1 – Sowing to emergence (BBCH Code 00-09)

P_2 – Emergence to rosette stage (BBCH Code 10-19)

P_3 – Rosette stage to stem elongation (BBCH Code 20-29)

P_4 – Stem elongation to branching (BBCH Code 30-39)

P_5 – Branching to flowering (BBCH Code 50-69)

P_6 – Flowering to capitulum and seed development (BBCH Code 71-79)

P_7- Capitulum and seed development to physiological maturity (BBCH Code 81-99)

Table: 3. Multiple linear regression equations fitted to explain the influence of prevailed meteorological parameters at different growth stages on seed yield of safflower

Parameters	Regression equation	R^2 value	n
Cumulative rainfall	-	-	-
Average maximum temperature	Yield = 243.37 (Tmax S-E) + 30.92 (Tmax E-RS) + 59.07 (Tmax BH-F) -6.71 (Tmax F-CS) – 75.80 (Tmax CS-H) – 5617.97	0.45	36
Average minimum temperature	Yield = 36.83 (Tmin S-E) – 174.43 (Tmin E-RS) *+ 214.95 (Tmin RS-SE) * - 4.94 (Tmin SE-BH) + 85.45 (Tmin BH-F) + 157.64 (Tmin F-CS) + 25.23 (Tmin CS-H) – 2893.06	0.56	36
Cumulative bright sunshine hours	Yield = -0.66 (BSSH E-RS) – 1.98 (BSSH SE-BH) – 3.79 (BSSH BH-F) * + 2.64 (BSSH CS-H) + 1679.92	0.38	36
Cumulative solar radiation	Yield = -0.17 (CSR E-RS) – 2.78 (CSR SE-BH) * – 2.39 (CSR BH-F) + 0.67 (CSR F-CS) + 2295.76	0.38	36
Maximum relative humidity	Yield = -27.44 (RH1 S-E) – 18.18 (RH1 RS-SE) – 14.69 (RH1 SE-BH) + 105.58 (RH1 BH-F) * + 5.18 (RH1 F-CS) – 3.75 (RH1 CS-H) – 2202.78	0.54	36

Minimum relative humidity	Yield = 17.44 (RH2 S-E) – 0.35 (RH2 E-RS) + 13.92 (RH2 RS-SE) +1.09 (RH2 SE-BH) + 0.69 (RH2 BH-F) – 12.91 (RH2 F-CS) -500.77	0.38	36
Wind speed	Yield = -226.02 (WS RS -SE) * – 261.88 (WS F-CS) * – 176.14 (WS CS-H) + 1782.72	0.45	36
Cumulative pan evaporation	Yield = -3.14 (PEVP F-CS) – 3.13 (PEVP CS-H) + 1692.71	0.23	36
Diurnal temperature range	Yield = -72.27 (DTR S-E) – 1.74 (DTR E-RS) – 185.06 (DTR RS-SE) * + 43.85 (DTR SE-BH) + 88.98 (DTR BH-F) * -28.24 (DTR F-CS) + 2584.35	0.50	36

Note: C RF - Cumulative rainfall Tmax - Average maximum temperature Tmin – Average minimum temperature

C BSSH – Cumulative bright sunshine hours C SR - Cumulative solar radiation RH I - Maximum relative humidity

RH II – Minimum relative humidity WS – Wind speed EVP – Pan evaporation

DTR - Diurnal temperature range

Table: 4. Seed yield, haulm yield and biological yield of safflower as influenced by dates of sowing and varieties

Treatments	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	biological yield (kg ha^{-1})	Harvest Index (%)
Main plot: Sowing dates (S)				
S_1: 07th October	1223	2797	4020	30.49
S_2: 21st October	1298	2833	4132	31.51
S_3: 04th November	1085	2559	3644	29.87
S_4: 18th November	1020	2486	3506	29.67
S.Em. (±)	32.2	78.0	102.7	0.81
C.D. @ p<0.05	111.7	270.2	355.4	NS
Sub plot: Varieties (V)				
V_1: Annigeri-1	1197	2747	3944	30.52
V_2: PBNS-86	1233	2802	4035	30.52
V_3: A-300	1040	2457	3497	30.11
S.Em. (±)	26.9	65.6	88.4	0.94
C.D. @ p<0.05	80.6	196.7	265.1	NS

was recorded significantly higher in crop sown on October 21st (2833 kg ha^{-1}), and it was on par with October 7th (2797 kg ha^{-1}). The lower haulm yield was recorded in crop sown on November 18th (2486 kg ha^{-1}). Among the three genotypes, PBNS-86 recorded a significantly higher haulm yield (2802 kg ha^{-1}), and it was on par with Annigeri-1 (2747 kg ha^{-1}). Significantly lower haulm yield was recorded in A-300 (2457 kg ha^{-1}). Significantly higher biological yield was recorded in crop sown on October 21st (4132 kg ha^{-1}), and it was on par with crop sown on October 7th (4020 kg ha^{-1}). However, a lower biological yield was produced on November 18th (3506 kg ha^{-1}). Among the varieties, PBNS-86 recorded a significantly higher biological yield (4035 kg ha^{-1}), which was followed by Annigeri-1 (3944 kg ha^{-1}). Significantly lower biological yield was recorded in A-300 (3497 kg ha^{-1}). Harvest index does not differ significantly due to dates of sowing. Numerically higher harvest index (31.51 %) was recorded with crop sown on October 21st and lower harvest index (29.67 %) was recorded with November 18th. Between the varieties, PBNS-86 has 0.41 per cent higher harvest index than A-300 which may be due to higher partitioning and translocation of photosynthates to the economic part because of higher vegetative growth and higher interception and utilization of solar radiation might have produced higher above ground dry matter.

3.3 Assessment of Weather and safflower seed yield relationship by Using Multiple Linear Regressions

Multiple linear regression equations fitted to know the influence of weather parameters at different growth stages on safflower grain yield (Table 4). Average maximum and minimum temperature contributed to yield variation of 45% and 56%, respectively from sowing to physiological maturity with the variation of temperature range from 28 to 34.7 ºC and 10.7 to 20.1 ºC respectively. Both cumulative bright sunshine hours and cumulative solar radiation are contributed to seed yield variation of 38% from emergence to capitulum and seed development stage. Similarly, maximum relative humidity (54%) effect on seed yield from sowing to physiological maturity and minimum relative humidity from sowing to capitulum and seed development stage accounted for 38% variation in seed yield. Wind speed contributed to seed yield variation of 45% from rosette stage to physiological maturity. Cumulative pan evaporation from flowering to physiological maturity stage accounted for 23% variation in seed yield and diurnal temperature range from sowing to capitulum and seed development stage accounted for 50% seed yield variation. Similar results are confirmed with Chakraborty *et al.* (2010).

4. CONCLUSION

From the present study it was concluded that safflower sown on October 21st recorded significantly higher seed yield and it was on par with crop sown on October 7th and lower yields were recorded on November 4th and November 18th. So early sowing is better than delayed sowing. Among varieties, PBNS-86 produced significantly higher seed yield and it was on par with Annigeri-1 . Lower seed yield were recorded in A-300. Higher temperature, lower relative humidity and diurnal temperature variations during later stages was unfavorable for safflower crop, which affect the pollen germination, pollen tube growth and fruit set. Weather-based regression models showed utility for predicting the above-ground biomass, yield, and yield components of safflower in Karnataka's central dry zone.

REFERENCES

Anonymous., 2021. Director's report, AICRP on Safflower and Linseed, 2021-22. ICAR-Indian Institute of Oilseeds Research, Hyderabad. pp. 32-33.

Anonymous., 2010. Ministry of Agriculture, Govt, of India.

Adesh G, Paliwal HB, and Nickey A. Different micro-environment condition on growth and yield of safflower (*Carthamus tinctorius* L.) in Prayagraj. *J. Pharmacogn. Phytochem*. 2020;**9**(2): 1385-1388.

Anil K, Pandey V, Shekh AM, and Manoj K. Temperature, photoperiod, sunshine duration, radiation use efficiency and weather parameter influence during life cycle of soybean (*Glycine max*. [L] Mirrll) production as well accumulation of dry matter. *Am-Euras. J. Agron.* 2008;**1**(2): 41-44.

Sawan ZM. Cotton production and climatic factors: Studying the nature of its relationship by different statistical methods. *Cogent Biol*. 2017;**3**(1): 129-288.

Shabana R, Ashraf A, Abd-El M, Hasna A, Gouda AH, and Hoda, SH. Impact of temperature fluctuation on yield and quality traits of different safflower genotypes. *World Essays Journal.,* 2013;**1**(3): 74-87.

Sahu J, Thakur NS, and Sourav G. Physiological parameters, yield and economics of safflower (*Carthamus tinctorius* L.) cultivars as affected by sowing dates. *Ann. Plant soil. Res*., 2017;**19**(1): 121 – 123**.**

Barla AK, Kote GM, and Deshmukh DD. Effect of sowing dates on yield and yield attributes of safflower genotypes. *Int. J. Curr. Microbiol. App. Sci.,* 2020;**9**(1): 361-366**.**

Chakraborty PK, Mukherjee A. and Mrinalbiswas. Diurnal variation in temperature and humidity profile within season canopy and its impact on growth process under different dates sowing. *J. Agrometeorol.*, 2010;**12**(1):69-73.