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Effect of Irrigation Scheduling on Growth, Yield and Economics of Hybrid Safflower

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ABSTRACT: **Safflower production and productivity are declining in recent past mainly due to cultivation under rainfed ecosystem on marginalized land coupled with poor crop management. Irrigation is an important factor affecting plant growth and yield especially in dryland areas. The proper time of irrigation application to crop is very important for increasing production and thereby increasing profitability. An experiment was conducted at Main Agricultural Research Station, UAS, Dharwad, Karnataka during *rabi*, 2019-20 with set of nine treatments. The treatments *viz*., T_1-Irrigation at rosette stage (30-35DAS), T_2-Irrigation at flower initiation stage (70-75 DAS), T_3-Irrigation at seed development stage (100 -105 DAS), T_4-At rosette and flower initiation stage, T_5-At rosette and seed development stage, T_6-At flower initiation and seed development stage, T_7-At rosette, flower initiation and seed development stages, T_8-Rainfed (without irrigation) and T_9 -Control A-1 variety (rainfed) with three replications. The crop cvs. NARI-NH-1 and A-1 was planted on Black soil. The results showed that safflower plant height (105.45 cm), LAI(2.11) and dry matter production (117.1g plant^{-1}) and seed yield (1759 kg ha^{-1}), stalk yield (4530 kg ha^{-1}) were significantly higher under three irrigations scheduled at rosette, flower initiation and seed development stages over control (1052 kg ha^{-1}, stalk yield 3438 kg ha^{-1} respectively). The extent of increase in yield was 40.19 per cent under three irrigations, 33.41 percent yield increase under two irrigations and 27.44 per cent yield increases under one irrigation scheduled at critical stage of the crop.**

Keywords: Safflower, Irrigation, Critical stages, NARI-NH-1 and Annigeri-1.

INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is one of the important *rabi* oilseed crops with immense potential for cultivation in dry areas of India. It belongs to family Asteraceae. Safflower is originally cultivated for dyes and cooking oil. Now seeds are used as edible oil, bird seed and as medicine for preventing heart diseases. Seed contains oil range from 28 to 32 per cent, nutritionally similar to sunflower oil having a sufficient amount of linoleic acid (78%) which is useful in reducing blood cholesterol. Typically grown on black clay soils on residual soil moisture and cultivated in different cropping regions in the world between the latitudes of 50° and 23° in both Northern and Southern hemispheres. Across the world, safflower is cultivated in 6,94,830 ha with a total production of 6,27,653 tonne. Kazakhistan is the leading producer of safflower grown for both seed and oil followed by India and Turkey (Anon., 2020).

India occupies second rank in area (14.78 %) as well as in production (8.76%) of the safflower grown across the world. Safflower is grown in India an area of 0.82 lakh ha with production of 0.69 lakh tonnes and productivity of 673 kg ha^{-1}. It is mainly grown in Maharashtra, Karnataka, Andhra Pradesh and Gujarat. In Karnataka, safflower is grown in 0.34 lakh ha and production is 0.27 lakh tonnes with productivity of 917 kg ha^{-1} (Anon., 2020).

The demand for vegetable oils for food purposes has considerable expansion of oilseed crops all over the world (Corleto *et al*., 1997). As the safflower is rich source of vegetable oil, it is necessary to increase yield, but day by day cultivation and productivity of safflower is decreasing due to cultivation of safflower under rainfed ecosystem on marginalized land, lack of drought resistant, disease resistant and high yielding varieties, cultivation under input starved conditions coupled with poor crop management, undue care of plant protection measures and lack of irrigation facilities and mainly cultivated as a dry land crop under scanty soil moisture.

Even though safflower thrives well under scanty moisture condition, irregular distribution of rain fall and limited rains are the main risk factor for growing of this crop in dry land agriculture. So it responds well to irrigation.

The reputation of safflower as a drought tolerant and moderately salinity tolerant crop and able to extract water at 1-2 m in the soil which is not available to majority of crops (Weiss, 2000), this is due extensive and deep root system and several fine laterals, allow safflower to survive in moisture deficit periods and also limit. About 90 per cent of oilseed crop grown in India is under rain fed, Almost 70 per cent of Karnataka's farmer depends on rain for their crops. In general rainfall is low and highly variable. Crop is traditionally cultivated in dry areas especially in black clay soil.

Among all the natural resources, water resources have unique position and water is crucial input for augmenting agricultural production towards sustainability in agriculture. Drought and water scarcity are the major factor affecting the agriculture crop production, particularly in arid and semi-arid region of the world. Irrigation is an important factor affecting the success of the crop particularly during critical stages of the plant growth. Safflower in dry areas requires less water but proper time of irrigation is most important at critical stages *i.e.* early vegetative (rosette), flowering and seed development stages. On other hand now-a-days hybrid varieties of safflower are available, but their performance is varying in different soil-plant-climatic condition. The productivity of the safflower need to be increased as this is a cash crop of medium and small holding farmers of Karnataka. Therefore the following field study was conducted to improve the production and productivity of safflower by scheduling of irrigation at critical growth stages of the crop, so as to make safflower cultivation successful by introducing safflower hybrid into Dharwad region of Karnataka.

MATERIAL AND METHODS

A field experiment was carried out during *rabi* 2019 – 2020 at the Main Agriculture Research Station, University of Agricultural Sciences, Dharwad (Karnataka) in plot number 107 of 'D' block, situated at 15^0 26' N latitude, 75^0 07' E longitude and at an altitude of 678 m above mean sea level. The research station comes under Northern transition zone (Zone-8) of Karnataka which lies between the Western Hilly Zone (Zone 9) and Northern Dry Zone (Zone-3). The mean annual rainfall for the past 69 years at MARS, Dharwad was 735.1 mm, which was well distributed from April to November. Maximum rainfall was received in the month of July (136.3 mm) followed by June (109.4 mm). Mean maximum temperature was 36.6°C (April). The experimental design was randomized complete block with nine treatments replicated thrice *viz*., T_1-Irrigation at rosette stage (30-35DAS), T_2-Irrigation at flower initiation stage (70-75 DAS), T_3-Irrigation at seed development stage (100-105 DAS), T_4-At rosette and flower initiation stage, T_5-At rosette and seed development stage, T_6-At flower initiation and seed development stage, T_7-At rosette, flower initiation and seed development stages, T_8-Rainfed (without irrigation) and T_9-Control A-1 variety with rainfed. Variety, NARI-NH-1 non spiny hybrid and Annigeri (A-1) spiny in nature were chosen for study.

The soil of experimental site was black clay soil (*Vertisol*) with neutral in reaction, (pH 7.1), normal in electrical conductivity (Ec) of 0.32 dSm^{-1}, medium organic carbon content (0.6 percent), low N (265 kilogram per hectare), medium in phosphorus and medium in potassium (31.7 and 293 kilogram per hectare), On 8^{th} November, 2019, brushing at a distance of 4 cm in shallow furrows was used for sowing. The experimental data obtained at different growth stages was complied and subjected to statistical analysis by adopting Fischer's method of analysis of variance technique as outlined by Gomez and Gomez (1984). The level of significance used in 'F' test was p = 0.05. The critical difference (CD) value was given in the table at 0.05 per cent level of significance.

RESULTS AND DISCUSSION

Growth conditions: Vegetative and reproductive growth of plants is vital in realizing the crops potential output. Plant height, number of primary and secondary branches $plant^{-1}$ at harvest (Table 1) was significantly higher under irrigation scheduled at rosette + flower initiation + seed development stages (105.44 cm, 17.57 and 27.60 at harvest, respectively) and followed by application of irrigation at rosette + flower initiation stage over control (97.88 cm, 16.23 and 25.76 at harvest, respectively) over control. Improvement in plant height owing to scheduling of irrigation at rosette, flower initiation and seed development stages mainly attributed to adequate soil moisture availability in the effective crop root zone at different phonological stages coupled with higher water potential and turgidity of the plant cells and leaf expansion which ultimately lead to higher assimilation as compared to rain fed crop. Nabipour *et al*. (2007); Jyosthna *et al*. (2013) have shown similar results.

Significantly higher Leaf area index at 90 Days after sowing under irrigation applied at rosette stage, flower initiation stage and seed development stage (2.50 LAI) over Control A-1 variety with rain fed (2.03 LAI) and hybrid with rainfed (1.98 LAI). However it was on par with irrigation scheduled at rosette stage and flower initiation stage (2.29 LAI).

Table 1: Growth and growth parameter of safflower as influenced by irrigation at different critical stages.

	Treatment details	Plant height (cm)				No. of branch/plant		Leaf area Index	
		30 DAS	60 DAS	90 DAS	At harvest	Primary branches	Secondary branches	90 DAS	At harvest
T_1	Irrigation at early vegetative / rosette stage (30-35 DAS)	19.25	64.92	85.85	94.07	13.96	23.70	2.11	1.86
T_2	Irrigation at flower initiation stage (70-75 DAS)	18.73	63.45	84.51	93.32	13.70	23.46	2.08	1.84
T_3	Irrigation at seed development stage (100 -105 DAS)	18.66	62.38	83.70	93.03	13.37	23.29	2.06	1.82
T_4	At rosette + flower initiation stage	20.51	66.73	90.91	97.88	16.23	25.76	2.29	1.98
T_5	At rosette + seed development stage	20.41	65.92	86.98	94.58	15.35	24.51	2.21	1.92
T_6	At flower initiation + seed development stage	20.16	65.18	86.23	94.26	15.04	24.29	2.16	1.90
T_7	At rosette + flower initiation + seed development stage	20.97	68.25	95.04	105.45	17.57	27.60	2.50	2.11
T_8	Rain fed (without irrigation)	19.90	61.47	81.33	87.60	11.73	16.84	1.98	1.75
T_9	Control A-1 variety with rainfed (package of practice)	20.12	53.46	65.70	71.22	12.14	17.56	2.03	1.77
	S.Em. ±	0.95	1.84	2.45	2.70	0.48	0.74	0.07	0.06
	C.D. (P = 0.05)	NS	5.51	7.34	8.12	1.44	2.24	0.21	0.18

At harvest, application of irrigation at rosette + flower initiation + seed development stages had a significantly higher leaf area index (2.11) over control (1.77), while it was on par with irrigation applied at rosette + flower initiation stage (1.98). The improvement in leaf area index was attributed to a considerable increase in assimilatory surface area, which resulted in higher photosynthetic accumulation. This could possibly be credited to optimum soil moisture availability and nutrient uptake. Sharma *et al*. (1999), reported that LAI increased significantly with increase availability of adequate soil moisture at different growing phonological stages and continuously with the advancement in crop age and the highest being at 90 DAS. Patel and Patel (1996) reported similar findings.

At different growth stages, total dry matter production differs significantly with irrigation schedule at critical stage. At 90 DAS and at harvest, dry matter was greater under irrigation applied at rosette stage + flower initiation stage + seed development stage (102.80 and 117.1 g plant^{-1}) than control A-1 variety with rainfed (81.86 and 85.8 g plant^{-1}) and lowest value observed under hybrid with rainfed (80.68 and 84.0 g plant^{-1}). This could be due to adequate soil moisture condition in the soil influencing plant root water absorption and leaf transpiration, which further helpful increasing in leaf area which would reflected on dry matter production.

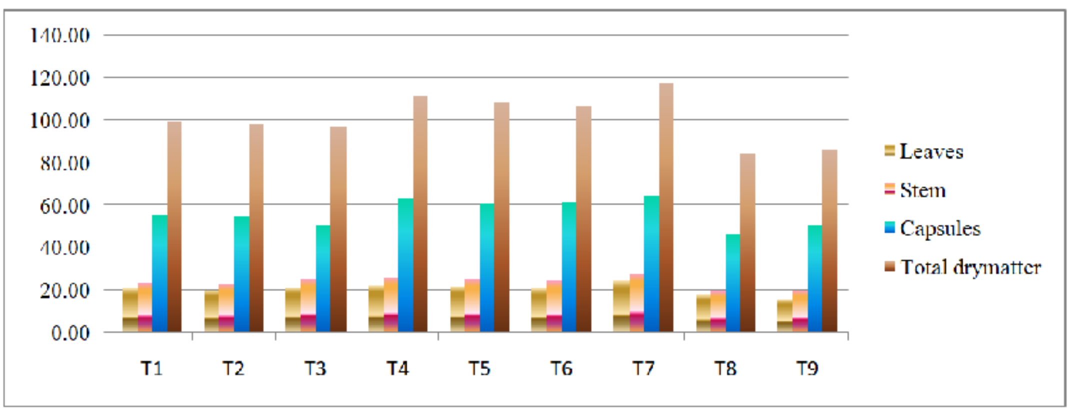


Fig. 1. Dry matter accumulation in leaves, stem, capitulum and total production (g plant^{-1}) of safflower as influenced by irrigation at critical stage.

Yield parameters: Yield is the complex quantitative character that involves interaction of physiological and environmental characters. Seed yield of safflower differed significantly due to application of irrigation at critical stages of the crop. The crop received irrigation at rosette + flower initiation + seed development stages found significantly higher seed yield (1759 kg ha^{-1}) over other treatments, while it was on par with irrigation at rosette + flower initiation stage (1649 kg ha^{-1}). Significantly lower seed yield were observed under control and hybrid with rainfed (1052 and 855 kg ha^{-1} respectively). The seed yield increased up to 49.19 per cent by providing irrigation at rosette, flower initiation and seed development stages as compared to rainfed condition. This might be due to scheduling irrigation at all growth stages created differential soil moisture resulted in positively increased number of fertile flowers consequently number of capitula and number of seed per plant thereby increased seed yield. Eslam, (2011). Khadtare (2018) reported similar findings, sufficient water supplied during different phenological stages resulted in increase in number of flower heads per plant and number of seed per plant thereby increased seed yield. The similar results were observed by (Orange and Ebadi 2012).

Reduced seed yield under rainfed condition mainly attributed to unavailability of moisture during different phenological stages and also increased competition for moisture between the plants thereby reduced the number of capsules per plant, number of seeds per capsules, 100 seed weight, were significantly differ and positive correlation with seed yield, this is mainly attributed to accelerated aging and reduced length of growing period and net photosynthesis. These findings are in close conformity with those of Koutroubas *et al*. (2000); Clavel *et al.,* (2005). Comparison among hybrid safflower under irrigated, hybrid safflower under rainfed and variety under rainfed conditions, hybrid safflower under irrigated condition recorded higher seed yield as compared to rainfed condition. This might be due to genetic potential of hybrids response towards applied irrigations. These findings are in close conformity with those of Shaneiter and Miller (1981); Zheng *et al*. (1993).

Data with respect to 100 seed weight didn't significantly influenced by scheduling of irrigation at critical growth stages. However numerically higher 100 seed weight (g) (5.66 g) found under irrigation received at rosette stage + flower initiation stage + seed development stage as compared to other irrigation treatments. Under stressed condition number of capsule per plant, seeds per capitula and seed weight per plant were significantly reduced (Abel, 1976). Reduced yield attributes in stressed conditions might be due to accelerated aging and reduced net photosynthesis was attributed (Clavel *et al*., 2005).

Irrigation applied at rosette + flower initiation + seed development stages had a significance in increased stalk yield (4530 kg ha^{-1}) over other treatments, while it was on par with irrigation applied at rosette stage + flower initiation (4325 kg ha^{-1}) and irrigation at rosette + seed development stage (4129 kg ha^{-1}). Control treatment was recorded significantly lower of stalk yield (3438 kg ha^{-1})

Stalk yield and Harvest index of hybrid safflower as influenced by irrigation scheduled at critical stages. Irrigation received at rosette stage + flower initiation stage + seed development stage recorded significantly higher stalk yield and Harvest index (4530 kg ha^{-1} and 28 %) over control treatment (3438 kg ha^{-1} and 19.61%). In case of stalk yield under minimum irrigation schedule, receiving irrigation at rosette stage, at flower initiation stage and at seed development stages were found to be on par with each other (3882, 3873 and 3838 kg ha^{-1} respectively). It might be due to optimum available of water content in the soil is a solvent, sense that it breaks down the minerals and nutrients that crop need from the soil, allowing them to absorb these helpful particles into plant systems. Similar result was reported by Jyosthna *et al*. (2013).

Economics: Higher gross return, net return and B-C ratio were noticed in (T_7) irrigation given at rosette, flower initiation and seed development stage to safflower (Rs. 63336, 34878 and 2.23 respectively) surpassed all other treatments except (T_4) irrigation given at rosette + flower initiation stage (Rs. 59364, 31542 ha^{-1} and 2.13, respectively) and lowest is with (T8) hybrid wit rainfed condition (Rs. 30792, 7732 ha^{-1} and 1.34 respectively). This could be due to higher seed yield and stalk yield in comparisons to rest of the treatments Khadtar *et al.* (2018); Singh *et al.* (1995).

CONCLUSION

Higher growth and yield attributes, yield and economics in the cultivation of hybrid safflower can be achieved under scheduling of irrigation at critical stages of the crop. On the basis of results obtained under present investigation and possible reasons for their unevenness having discussed, the following conclusions were drawn. If plenty of irrigation water is available, application of irrigation at rosette + flower initiation + seed development stages are required for optimization of highest seed yield (1759 kg ha^{-1}), stalk yield (4530 kg ha^{-1}), total net monetary returns (34878 ha-1) and B:C ratio (2.23). If water is sufficient for only two irrigations, irrigation scheduling at rosette + flower initiation stages is essential for attaining highest seed yield (1649 kg ha^{-1}), stalk yield (4325 kg ha^{-1}), total net monetary returns (31542 ha^{-1}) and B:C ratio (2.13). If water available for one irrigation scheduling either at rosette stage or flower initiation stage or seed development stage was beneficial as they are found on par with each other with respect to growth, yield and yield parameters.

Table 2: Seed yield and yield parameter of safflower as affected by irrigation at critical stages.

	Treatments	Yield attributes						
		Number of capsules per plant	Number of seeds per capsules	Seed weight per plant (g)	Test weight (100g)	Seed yield (kg/ha)	Stalk yield (kg/ha)	Harvest Index (%)
T_1	Irrigation at early vegetative / rosette stage (30-35 DAS)	20.55	23.78	27.54	5.35	1479	3882	27.46
T_2	Irrigation at flower initiation stage (70-75 DAS)	20.47	23.52	26.83	5.28	1461	3873	27.39
T_3	Irrigation at seed development stage (100 -105 DAS)	20.45	23.23	26.23	5.23	1415	3838	26.95
T_4	At rosette + flower initiation stage	22.03	25.07	30.38	5.53	1649	4325	27.62
T_5	At rosette + seed development stage	20.92	24.85	29.53	5.42	1572	4129	27.57
T_6	At flower initiation + seed development stage	20.73	24.56	28.97	5.38	1533	4049	27.47
T_7	At rosette + flower initiation + seed development stage	23.49	26.55	32.34	5.66	1759	4530	28.00
T_8	Rain fed (without irrigation)	18.41	17.98	18.25	5.14	855	3502	19.61
T_9	Control A-1 variety with rainfed (package of practice)	18.89	19.48	19.50	5.19	1052	3438	23.68
	S.Em. ±	0.73	0.84	0.87	0.16	52.6	139	1.25
	C.D. (P = 0.05)	2.20	2.51	2.62	NS	158	416	3.76

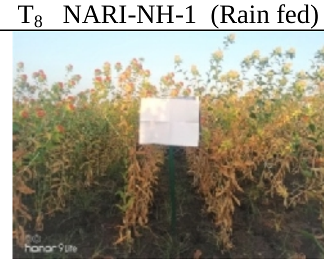
Table 3: Economics of safflower as affected by irrigation at critical stages.

	Treatments	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B- C ratio
T_1	Irrigation at early vegetative / rosette stage (30-35 DAS)	27956	53,232	26,046	1.96
T_2	Irrigation at flower initiation stage (70-75 DAS)	27956	52,608	25,422	1.94
T_3	Irrigation at seed development stage (100 -105 DAS)	27956	50,928	23,742	1.87
T_4	At rosette + flower initiation stage	28592	59,364	31,542	2.13
T_5	At rosette + seed development stage	28592	56,580	28,758	2.03
T_6	At flower initiation + seed development stage	28592	55,188	27,366	1.98
T_7	At rosette + flower initiation + seed development stage	29228	63,336	34,878	2.23
T_8	Rain fed (without irrigation)	25030	30,792	7,732	1.34
T_9	Control A-1 variety with rainfed (package of practice)	23870	37,884	15,984	1.73
	S.Em. ±	-	1886	1644	0.07
	C.D. (P = 0.05)	-	5687	4929	0.20

T_9 Control – A1 variety with rainfed

T_8 NARI-NH-1 (Rain fed)

T_4 – Irrigation at rosette + flowering initiation stage



T_7- Irrigation at rosette+ flower initiation+seed development stage

Fig. 1. Response of safflower under irrigation and rainfed situation.

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