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Growth, yield and water productivity of hybrid safflower as influenced by scheduling of irrigation at critical stages

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Abstract
An experiment was conducted at Main Agricultural Research Station, UAS, Dharwad, Karnataka during rabi, 2019-20 to study the growth, yield and water productivity of safflower as influenced by scheduling of irrigation at critical stages. The experiment was laid out in Randomized Complete Block design with 3replication. There were 9 treatments viz., T_1-Irrigation at rosette stage (30-35 DAS), 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). The crop cvs. A-1 and NARI-NH1 was sown on Black clay soil. The results indicated that safflower no.of primary and secondary branches (15 and 24.27), and seed yield (1759 kg ha^{-1}) and oil yield (530.4 kg ha^{-1}) were significantly higher with scheduling of three irrigations at rosette + flower initiation + seed development stages as compared to control (1052 kg ha^{-1}, oil yield 292.3 kg ha^{-1} respectively). Whereas root length (121.69 cm), root weight (84.05 g) and water productivity (8.92 kg m^3) has recorded higher under rainfed condition. The extent of increase in yield was 40.19% under 3 irrigations, 33.41% yield increase under 2 irrigations and 27.44% yield increases under single irrigation scheduled at critical stage of the crop.

Keywords: Safflower, critical stages, water productivity, irrigation, NARI-NH-1 and annigeri-1

Introduction

Safflower (*Carthamus tinctorius* L) (Kusumbha, kusum, kardi) is a cool (rabi) season crop, it belongs to Asteraceae family and well branched, tistle like winter annual plant, typically with numerous long sharp spine on the leaves and has been under cultivation in India for its brilliantly coloured florets and the orange red dye (carthamin) extracted from them and traditionally grown for its seeds. Safflower contains 24-36% oil which is flavourless, colourless and nutritionally similar to sunflower oil and 11-24% protein and provides three principal products: oil, meal and birdseed. Safflower oil consists of two types: those high in monounsaturated fatty acid (oleic) and those high in polyunsaturated fatty acid (linoleic) which is useful in desirable frying characteristics of stability and a blend flavor (Yeilaghi *et al*., 2012) [16] and reducing blood cholesterol. Usually grown on black soil on residual soil moisture and cultivated in different cropping regions in the world between the latitudes of 23 ° and 50 ° in both Southern and Northern hemispheres.

India occupies second rank in area (14.67%) as well as in production (9.02%) of the safflower grown across the world. Safflower is grown in India an area of 0.84 lakh ha with production of 0.67 lakh tonnes and productivity of 679 kg ha^{-1}. It is mainly grown in Telengana, Maharashtra, Andhra Pradesh, Karnataka and Gujarat. In Karnataka, safflower is grown in 0.35 lakh ha and production is 0.28 lakh tonnes with productivity of 921 kg ha^{-1} (Anon., 2022). As the safflower is major source of vegetable oil, it is necessary to increase production, but currently, cultivation and productivity of safflower is decreasing might be to cultivation of safflower under dry land condition on marginalized area, lack of suitable drought resistant varieties, disease resistant and high yielding varieties, cultivation under input starved conditions coupled with improper crop management, undue care of plant protection measures and lack of irrigation. Safflower is considered as a drought-tolerant crop, able to extract water (soil moisture) at 1.5-2 m from the soil that is not available to the majority of crops (Majidi *et al*., 2011) [7]. The importance of oil crops such as safflower has augmented in recent years, as this plant successfully acclimatizes to dry land conditions and is extremely drought resistant due to its extended root system enabling access to water down to 2-3 m in the soil (Bagheri and Sam-Daliri, 2011) [2].

About 85-90 percent of oilseed crops are grown in India is under rain fed condtion, Almost 70-75 percent of Karnataka's farmer depends on rain for their crops. In general there is wide variation in the quantity of rainfall, highly erratic, undependable and highly variable either in excess or deficit. Crop is traditionally cultivated in dry areas especially in black clay soil.

Among all the crop production resources, water resource have distinctive position, water is a critical input for agricultural production and plays an important role in food security. Water scarcity and drought are the main factor affecting the agriculture crop production, particularly in arid and semi-arid region of the India. Irrigation is an important agronomic practice, significantly influences on crop growth and development, hence success of the crop particularly during critical stages of the plant growth depends on irrigation practices.

Safflower in dry land conditions require a lesser amount of water but proper time of irrigation is most important at critical stages *i.e.* rosette (early vegetative), flowering and seed development stages along with this currently safflower hybrid are available, but their performance is varying in different soil-plant-climatic condition. The production and productivity of the safflower is need to be increased as this is a cash crop of small and medium holding farmers of Karnataka. Availability of optimum moisture in the soil enhances the efficiency of applied nutrients. Any reduction of soil moisture at these stages will considerably reduce the grain yield. Therefore, it is necessary to evaluate irrigation scheduling so as to realize higher yield and economic returns. Hence the following field study was carried 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

During 2019-20 *Rabi*, a field experiment was conducted at Main Agriculture Research Station, University of Agricultural sciences, Dharwad (Karnataka) in plot number 108 of 'D' block located at 15° 26' North latitude and 75° 07' East longitude at an altitude of 678 m above mean sea level and research station comes under Zone-8 (Northern Transition Zone of Karnataka which occur between Northern Dry Zone (Zone-3) and Western Hilly Zone (Zone-9). The total amount of rainfall received during 2019-20 was 1316.2 mm distributed in 72 rainy days. The total amount of rainfall received during cropping period was 11.8 mm (8th Non to 15th Mar) distributed in 2 rainy days. The mean maximum temperature recorded during cropping period (19th Feb to 25th Feb) was (33.13 °C), lowest temperature was in January-2020 (15.24 °C). The relative humidity was observed highest (89.86 percent) during 3rd Dec to 9th Dec of 2019 and lower relative humidity was observed in 19th Feb to 25th Feb. (24.71 percent).

There were 9 treatments i.e. T_1-Irrigation at rosette stage (30-35 DAS), 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 T9-Control A-1 variety with rainfed, laid in RCBD with three replication. Cultivars used were NARI-NH 1 (hybrid) which was non spine and Annigere-1 (A-1) variety spine in nature. Test site was consist of black clay soil with nuetral (pH 7.1), Electrical conductivity (Ec) of 0.31 dSm^{-1}, medium organic carbon content (0.57 percent), low N (265.2 kilogram per hectare), high phosphorus and high potassium (32.1 and 295 kilogram per hectare), On November 8th, 2019, brushing at a distance of 30 cm in shallow furrows was used for sowing.

The crop was grown in *rabi* under irrigation. One common irrigation was scheduled with sprinkler system to the all treatments including control for good germination, uniform and proper establishment of the seedlings after sowing and subsequent irrigations were scheduled as per the treatments and according to critical growth stages of crop.

Table 1: The crop was grown in *rabi* under irrigation. One common irrigation was scheduled with sprinkler system to the all treatments including control for good germination

Sr. No.	Critical growth stage	Crop age (DAS)	Actual irrigation schedule (DAS)
1.	Rosette stage	30-35	35
2.	Flowering stage	70-75	75
3.	Seed development	100-105	105

Depth of water maintained was 5cm. The quantity of water discharge was measured by Parshall flume with 7.5 cm throat section and discharge values were recorded. Prior to each irrigation soil moisture content was determined by using Theta probe at a depth of 0-15, 15-30 cm and 30 -60 cm by gravimetric method. The crop was cultivated by following standard package of practices for all other aspects. For all the treatments, the recommended dose of nitrogen, phosphorus and potassium was applied commonly. The experimental data found 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) [3]. 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 percent level of significance.

Result and Discussion

Growth attributes: Optimum plant density varies markedly with available moisture, plant height, branching ability, and fertility status of soil. Optimum plant population plays important role for getting maximum output. In plant stand both at initial (at 30 DAS) and final crop stand (at harvest) was found to be non-significant due to irrigation schedules at different critical stages. However, numerically higher plant stand was observed in (T_7) irrigation applied at rosette + flower initiation + seed development stages (54275 plants/ha) after harvest and numerically lower plants occur in (T_8) hybrid with rain fed (51860 plants/ha) after harvest this was mainly attributed to regular irrigation at the time of critical stages their by crop was experienced with good congenial environment with respect to climatic condition and moisture, which in turn help for nutrient availability to the crop. Similar results were reported with respect to moisture by Singh and Singh (1989) [14].

Influence of irrigation on number of primary and secondary branches was found. There were increases in number of branches with the advancement in age of the plant in all the treatment. Significantly higher number of primary and secondary branches were observed (15.00 and 24.27) under irrigation scheduled at (T_7) rosette + flower initiation + seed development stages, which was on par with the irrigation schedule at (T_4) rosette and flower initiation stages (13.71 and 23.19). Lesser number of primary and secondary branches plant^{-1} was observed under (T_8) hybrid under rain fed and (T_9) control- A-1 with rain fed (10.88, 11.15 and 15.23, 15.90 respectively). This was mainly due to optimum moisture available in effective crop root zone, which might have benefited to the plant at different critical stages, resulted in more uptake of nutrients resulted in higher synthesis of nuclic acid, amide substances in growing regions and meristematic tissue which ultimately enhances optimum cell division, cell elongation which enhance the growth parameters of the crop. Similar results obtained and are in confirmation with findings of Nabipour *et al*. (2007) [9].

Root studies: A vigorous, adaptive root system is significant for better uptake of water and nutrients, which in turn increases crop growth and development thereby grain yield, especially under stress conditions. Therefore, the measurement of root-related traits is important in agriculture as those of the shoot. Root parameters significantly affect the irrigation schedules and acquirement of nutrients for growth and development in safflower. The data on root length was clearly indicates the fact that the root length decreases with increases with number of irrigation. The longest root length was found with (T_9) A-1 variety with rain fed (control) treatment (19.56, 62.23 and 121.69 cm in 35, 75 and 105 DAS respectively).However it was par with (T_8) hybrid with rain fed (without irrigation) treatment (18.90, 60.54 and 118.35 cm in 35, 75 and 105 DAS respectively). Shortest roots were found irrigation scheduled at (T_7) rosette + flower initiation + seed development stages (15.00, 51.78 and 95.39 cm with respect to 35, 75 and 105 DAS) this is mainly due to under rainfed conditions, the roots are in contact with a greater volume of soil to absorb more water. Deficit in water, nutrient supply in rainfed condition resulted greater below allocation of physiological resources and increased root growth and its root dry matter accumulation, which gradually decreased with increase in moisture and moisture supply under irrigation with comfortable nutrient supply. These results lend support to earlier findings of Hoogen Boom, (1987) [4]; Merrill *et al.*, (1994) [8] and Hanson *et al.* (1999) [5]. In case of root dry weight higher root dry weight was observed under A-1 variety with rain fed (control) treatment (12.45, 40.23 and 84.05 g in 35, 75 and 105 DAS respectively) which was followed by hybrid with rain fed (without irrigation) treatment (11.67, 38.48 and 80.61 g in 35, 75 and 105 DAS respectively) this could be due to the fact that increased root length, number of roots. But in case of irrigation received plot root dry weight is less mainly due moisture availability through irrigation at different phonological stages facilitate easily absorption of nutrients might have lead to less allocation of physiological resources below the ground. Increased soil moisture availability through frequent irrigation resulted in more shallow depths of root growth and its dry matter. These findings are confirmed with those of Hoogen Boom, (1987) [4].

Seed yield, Oil yield and Oil content: Scheduling of irrigation at rosette stage + flower initiation stage + seed development stage (T_7) recorded significantly higher seed yield (1759 kg ha^{-1}) as compare to other treatments, however it was on par with plot received irrigation at rosette stage + flower initiation (1649 kg ha^{-1}). Significantly lower seed yield (kg ha-1) observed under (T_9) control and (T_8) hybrid with rain fed (1052 and 855 kg ha-1 respectively). Application of irrigation at two Scheduling of irrigation at two critical stages, viz., receiving of at rosette + flower initiation stage (T4), irrigation at rosette stage + seed development stage (T5) and at flower initiation + seed development stage (T6) were observed on par with each other (1649, 1572 and 1533 kg ha-1 respectively). Under minimum irrigation schedule, receiving irrigation at rosette stage (T1), at flower initiaon stage (T2) and at seed development stage (T3), were found on par with each other (1479, 1461 and 1415 kg ha-1 respectively). This was due to availability of adequate soil moisture throughout crop growth period and helps uptake of nutrients, thereby cell enlargement due to turgor pressure and cell division which finally increases plant growth parameters which ultimately gave higher yield by (Parameshnaik *et al.*, 2022) [11]. Maintaining of sufficient moisture during different phonological stages helps in production of higher photosyntates and transfer from source to sink. The similar results were observed by (Orange and Ebadi. 2012) [10].

Similarly oil yield of safflower has shown varied at application of irrigation at critical stages and noticed to be significant. Plot received irrigation at rosette stage + flower initiation stage + seed development stage (T_7) and was recorded higher oil yield (530.4 kg ha^{-1}) and it was on par with receiving irrigation at rosette + flower initiation stage (487.5 kg ha^{-1}) Significantly lower seed yield (kg ha-1) observed under (T_9) control and (T_8) hybrid with rain fed (292.3 and 241.1 kg ha^{-1} respectively). This mainly due the fact that maximum seed yield was noticed. Similar result was reported by Yusuf *et al*. (1981) [17] and Suryawanshi *et al*. (2007) [15]. And numerically higher oil content was observed in plot received irrigation at rosette + flower initiation + and seed development stage (30.11 percent) followed by irrigation received at rosette stage + flower initiation stage (29.56 percent). Which might be due to irrigation applied at critical enhancing the carbohydrate accumulation leading to seed oil percentage. These findings are in conformity with those reported by Zaman and Das (1991) [18]; Patel and Patel (1994) [12].

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

	Treatments	Plant stand at 30 DAS density/ha	Plant stand at harvest density/ha	No. of primary branches per plant	No. of secondary branches per plant
T_1	Irrigation at early vegetative/rosette stage (30-35 DAS)	55007	53033	12.41	20.40
T_2	Irrigation at flower initiation stage (70-75 DAS)	54996	52983	12.35	20.31
T_3	Irrigation at seed development stage (100-105 DAS)	54898	52775	12.06	20.00
T_4	At rosette + flower initiation stage	55159	54193	13.71	23.39
T_5	At rosette + seed development stage	55086	53919	12.81	21.57
T_6	At flower initiation + seed development stage	55026	53403	12.47	21.39

T_7	At rosette + flower initiation + seed development stage	55226	54275	15.00	24.27
T_8	Rain fed (without irrigation)	54853	51860	10.88	15.23
T_9	Control A-1 variety with rainfed (package of practice)	54833	52357	11.15	15.90
	S.Em. ±	1646	1071	0.44	0.57
	C.D. (P = 0.05)	NS	NS	1.33	1.72

Table 2: Root length (cm) and root weight (g) of safflower as influenced by scheduling of irrigation at critical stages

	Treatments	Root length (cm) at 35 DAS	Root length (cm) at 75 DAS	Root length (cm) at 105 DAS	Root dry weight (g) 30 DAS	Root dry weight (g) 60 DAS	Root dry weight (g) 90 DAS
T_1	Irrigation at early vegetative/rosette stage (30-35 DAS)	18.30	58.34	107.30	10.45	35.25	78.29
T_2	Irrigation at flower initiation stage (70-75 DAS)	17.28	55.43	108.54	10.17	33.89	75.65
T_3	Irrigation at seed development stage (100-105 DAS)	19.30	56.39	98.94	9.83	32.34	74.59
T_4	At rosette + flower initiation stage	16.34	54.57	98.10	9.20	30.25	71.54
T_5	At rosette + seed development stage	16.20	53.27	97.45	9.15	30.00	70.23
T_6	At flower initiation + seed development stage	15.76	52.87	94.41	9.34	31.24	73.20
T_7	At rosette + flower initiation + seed development stage	15.00	51.78	95.39	9.00	29.78	70.01
T_8	Rain fed (without irrigation)	18.90	60.54	118.35	11.67	38.48	80.61
T_9	Control A-1 variety with rainfed (package of practice)	19.56	62.23	121.69	12.45	40.23	84.05
	S.Em. ±	1.12	2.91	4.41	0.46	1.54	2.09
	C.D. (P = 0.05)	2.38	6.18	9.35	1.39	4.62	6.27

Table 3: Seed yield, oil yield and oil content of safflower as influenced by scheduling of irrigation at critical stages

	Treatment details	Seed yield (kg/ha)	Oil content (%)	Oil yield (kg ha^{-1})
T_1	Irrigation at early vegetative/rosette stage (30-35DAS)	1479	28.40	419.5
T_2	Irrigation at flower initiation stage (70-75 DAS)	1461	28.10	410.7
T_3	Irrigation at seed development stage (100-105 DAS)	1415	28.08	397.4
T_4	At rosette + flower initiation stage	1649	29.56	487.5
T_5	At rosette + seed development stage	1572	28.59	448.5
T_6	At flower initiation + seed development stage	1533	28.40	435.6
T_7	At rosette + flower initiation + seed development stage	1759	30.11	530.4
T_8	Rain fed (without irrigation)	855	28.10	241.1
T_9	Control-A-1 variety with rain fed (package of practice)	1052	27.87	292.3
	S.Em. ±	52.6	2.83	17.90
	C.D. (P = 0.05)	158	NS	53.68

Table 4: Water productivity of safflower as influenced by scheduling of irrigation at critical stages

	Treatments	Total irrigation (m^3 ha^{-1})	Rainfall (m^3)	Total water applied (m^3 ha^{-1})	Water productivity (kg m^{-3})
T_1	Irrigation at early vegetative/rosette stage (30-35 DAS)	361.11	118	479.11	3.09
T_2	Irrigation at flower initiation stage (70-75 DAS)	376.16	118	494.16	2.96
T_3	Irrigation at seed development stage (100-105 DAS)	368.63	118	486.63	2.91
T_4	At rosette + flower initiation stage	737.27	118	855.27	1.93
T_5	At rosette + seed development stage	729.75	118	847.75	1.85
T_6	At flower initiation + seed development stage	744.79	118	862.79	1.78
T_7	At rosette + flower initiation + seed development stage	1105.90	118	1223.90	1.44
T_8	Rain fed (without irrigation)	0.00	118	118.00	7.25
T_9	Control A-1 variety with rainfed (package of practice)	0.00	118	118.00	8.92
	S.Em. ±	--	--	--	0.29
	C.D. (P = 0.05)	--	--	--	0.86

Water productivity

The data on water productivity detailed in table: 3. The water productivity as influenced by scheduling of irrigation at critical stages in safflower. The quantity of water applied in each irrigation treatments was 361.11, 376.16, 368.63, 737.27, 729.75, 744.79 and 1105.90 cubic meter and inclusive of effective rainfall 11.8 mm in two rainy days. The total quantity of water available at different treatments was 479.11, 494.16, 486.63, 855.27, 847.75, 862.79 and 1223.90 cubic meter in different treatments in single irrigation at rosette stage (T_1), at flower initiation stage (T_2) and at seed development stage (T_3), two irrigation at rosette stage + flower initiation stage (T_4), at rosette stage + seed development stage (T_5) and at flower initiation stage + seed development stage (T_6) and three irrigation at rosette stage + flower initiation stage + seed development stage (T_7) respectively. Water productivity can be presented in terms of yield realised per cubic meter of water applied. Among all the treatments, irrigation received at rosette stage + flower initiation stage + seed development stage (T_7) recorded significantly lowest water productivity (1.44 kg m^{-3}). Water productivity shows the decreasing trend with increase in amount of water quantity applied. The rain fed treatment (T_9) recorded significantly highest water productivity (8.92 kg m^{-3}) over other irrigation treatments. This might be due to more irrigation frequencies resultant in decreasing in water productivity (Pillai *et al*., 1990) [13]. Also more evapotranspiration takes place, runoff water and more seepage loss of water. Patel and Patel (1994) [12] concluded that water productivity increased with decrease in irrigation level. This is mainly due to better root growth resulting in improved moisture utilization. A similar finding was also concluded by Singh and Singh (1989) [14].

Conclusion

Higher growth parameters, seed yield, oil yield and water productivity in the production of safflower can be attained under irrigation application at critical stages of crop. Keeping in sight the results obtained under the investigation and probable reasons having discussed the following conclusion were drawn. If adequately irrigation water is available, application of irrigation at rosette + flower initiation + seed development stages are required for optimization of higher seed yield (1759 kg ha^{-1}), oil yield (530.4 kg ha^{-1}), oil content (30.11 percent) and higher water productivity obtained under (8.92 kg m^3). If adequately irrigation water is available, application of irrigation at rosette + flower initiation stages is needed for attaining higher seed yield (1649 kg ha^{-1}), oil yield (487.5 kg ha^{-1}), oil content (29.56 percent) and water productivity (1.92 kg m^3). 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.

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