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Studies on soil moisture conservation practices and planting geometry on growth, yield and economics of safflower (*Carthamus tinctorius* L.)

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Abstract
A field experiment was conducted to study the Influence of soil moisture conservation practices and planting geometry on growth, yield and economics of safflower under northern dry zone (Zone-3) of Karnataka during *Rabi*, 2017-18 at ARS Annigeri, UAS, The treatments were replicated thrice in split-plot design. The main plot treatments consisted of soil moisture conservation practices (Flat bed, compartment bunding and tied ridge) and sub plot treatments consisted of planting geometry (S1-45 cm ×20 cm, S2- 60 cm × 15 cm, S3- 60 cm × 20 cm and S-4 60 cm × 30 cm).Maximum seed yield, stalk yield and test weight of safflower was recorded with tied ridges (1,061 kg/ha, 2,895 kg/ha and 7.55 g respectively). Sowing of safflower at spacing of 45 cm ×20 cm recorded significantly higher seed yield (1,093 kg/ha) and stalk yield (2,961 kg/ha) and the growth parameters *viz*., total dry matter production (108.67), plant height (72.44 cm), number of primary branches per plant (16.33) and number of secondary branches per plant (31.89) at harvest with same planting geometry. The economic analysis of the system revealed that significantly higher gross returns (₹ 29,708/ha), net returns (₹ 12,996/ha) and B-C ratio (1.79) was recorded with tied ridges. Among the different spacing, 45 cm × 20 cm recorded significantly higher gross returns (₹ 30,616/ha) net returns (₹14,216/ha) and B-C ratio (1.87). The tied ridge and planting geometry of 45 cm × 20 cm found significantly superior in improving growth and yield of safflower.

Keywords: Conservation, planting geometry, growth, yield, economics, safflower

Introduction
Safflower is mainly grown for its seeds, flowers, used for colouring and flavouring of foods, making dyes, especially before cheaper aniline dyes became available and medicines. Safflower is a highly branched, herbaceous, thistle-like annual or winter annual, usually with many long sharp spines on the leaves. Plants are 30 to 150 cm tall with globular flower heads (capitula) and commonly with brilliant yellow, orange or red flowers. Achenes are smooth, four-sided and generally lack pappus. As safflower is highly drought and salt tolerant crop than other oilseed crops, it is especially suited for dry and salty areas where other oilseed crops are facing difficulty to grow [3, 7]. Also, low cost of production and low water and nutrient needs appeal to farmers as an alternative to other crops. However, safflower yields are generally lower than the yield of other oilseed crops [9].

Safflower oil is preferred much as it is rich in poly unsaturated fatty acid (78% linoleic acid) which reduces blood cholesterol level [2]. Safflower seed contains 28-34% of oil, which is flavor less and colour less and nutritionally similar to sunflower oil. But the productivity of safflower is very low as the crop is cultivated under rainfed conditions. However, there is ample scope to increase safflower yields and quality by adopting suitable water management practice. Lower productivity calls for greater attention to increase the productivity of the crop by increasing moisture status of the soil besides other resources [4, 5].

Globally safflower is being cultivated over an area of 0.74 M ha with an annual production around 0.6 M t and productivity about 872 kg/ha. Among the major safflower cultivating countries, the productivity is the highest in Mexico (1200 kg/ha) followed by India (627 kg/ha). In India the area under safflower is estimated around 1.27 lakh ha with an annual production of 5.3 lakh tonnes accounting for over half of the global safflower production. Karnataka and Maharashtra are the major safflower growing states, which contribute to more than 90 per cent of India's total production of safflower. In Karnataka, the safflower occupied an area of 0.54 lakh ha with on annual production of 0.30 lakh tonnes and productivity of 563

kg/ha [1]. More than 50 per cent of total area and production of safflower at national level comes from only five districts of Maharashtra (Parbhani, Usmanabad, Hingoli, Latur and Jalna) and two districts of Karnataka (Bidar and Gulbarga).

The dryland areas in India face twin problems of inadequate availability of soil moisture and poor fertility for successful crop production. Huge areas amounting 108million hectares are grouped under drylands, which account 66 per cent of the total cultivated area. The dryland farming is gamble in nature due to vagaries and vicissitudes of the mansoon. After sowing of *rabi* crops in September to October, Rainfall is a chance factor. Therefore, the soil moisture combined with well weather conditions prevailing thereafter largely determines the productivity of *rabi* crops. There is need to adopt any conservation measures that would help to retain maximum rain water in the soil profile for better crop response during winter situations. *In-situ* moisture conservation practices as well as deep inter cultivation are some of the measures to increase rain water retention and its conservation in the soil. Conservation of greater rain water in the soil profile is just not sufficient but the conserved moisture should be utilized most efficiently as result of better management practices.

Material and methods

A field experiment was conducted to study the Influence of soil moisture conservation practices and planting geometry on growth, yield and economics of safflower under northern dry zone (Zone-3) of Karnataka during *Rabi*, 2017-18 at ARS Annigeri, UAS, The treatments were replicated thrice in split-plot design. The main plot treatments consisted of soil moisture conservation practices (Flat bed, compartment bunding and tied ridge) and sub plot treatments consisted of planting geometry (S1-45 cm ×20 cm,S2- 60 cm × 15 cm,S3-60 cm × 20 cm andS4- 60 cm × 30 cm). The soil moisture conservation practices were implemented a month before of sowing with an objective of harvesting the pre *mansoon* rain water. The planting was done on 20th October 2017 as per the different planting geometry.

Results and discussion

Influence of soil moisture conservation practices and planting geometry on growth and yield of safflower: Number of capsules per plant, seeds per capsules, seed weight per plant, seed yield and stalk yield significantly influenced by different moisture conservation practices and planting geometry (Tables 1, 2 & 3). *In-situ* moisture conservation practices had a profound influence on the seed yield of safflower. Tied ridges recorded 1,061 kg/ha of seed yield, which was significantly higher than in compartment bunding (940 kg/ha) and flat bed system (924 kg/ha). The per cent increase in the seed yield of safflower was 15 over flat bed system. The higher seed yield of safflower in tied ridges was mainly attributed to higher soil moisture content at different soil depths than in flat bed. The seed yield was significantly influenced by different spacings. Sowing of safflower at spacing of 45 cm x 20 cm recorded significantly higher seed yield (S_1: 1,093 kg/ha) over a spacing of 60 cm x 30 cm (S_4: 907 kg/ha), the growth parameters *viz*., total dry matter production (108.67), plant height (72.44 cm), number of primary branches per plant (16.33) and number of secondary branches per plant (31.89) at harvest with same planting geometry. This increase of seed yield of 20.5 % over a spacing of 60 cm x 30 cm with the highest plant density was mainly attributed to the higher number of plants and heads per unit area at harvest [10]. However, yield attributes like number of branches/plant, number of heads/plants, test weight and seed yield/plant were significantly higher at wider row spacing [3, 6] reported that sowing of safflower at spacing of 45 cm x 20 cm recorded significantly higher seed yield (1650 kg/ha) over a spacing of 60 cm x 30 cm. [5, 7] also observed an increased yield with corresponding increase in plant population.

Influence of soil moisture conservation practices and planting geometry on economics of safflower: The critical issue for wider practicing of *in-situ* moisture conservation practices in dry land communities appear to be of the practical and economical feasibility at the farm level. In the present study, tied ridges recorded significantly higher gross return (C_3:₹29,708/ha) than flat bed system (C_1:₹25,897/ha). The net returns and benefit: cost ratio followed the trend of gross returns. The higher monetary advantage with *in-situ* moisture conservation practices was due to higher yield of safflower as a consequent to the increased moisture build up prior to its sowing. The gross returns, net returns and B-C ratio was significantly influenced by different spacings. Sowing of safflower at spacing of 45 cm ×20 cm recorded significantly higher gross returns (S_1:₹30,616/ha), net return (S_1:₹14,216/ha) and B:C ratio (S_1: 1.87) as compared spacing of 60 cm ×30 cm (S_4: ₹25,408/ha, ₹9,421/ha and 1.59 respectively) [6, 8].

Table 1: Effect of different soil moisture conservation practices and planting geometry on plant height of safflower at different growth stages

Treatment		Plant height (cm)											
		30 DAS				60 DAS				At harvest			
		Moisture conservation practices (M)				Moisture conservation practices (M)				Moisture conservation practices (M)			
		C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
Spacing (S)	S_1	16.67	18.00	21.33	18.67	51.00	54.00	56.33	53.78	65.33	70.67	71.33	69.11
	S_2	18.33	20.33	22.67	20.44	52.00	54.67	57.00	54.56	67.33	71.00	71.00	69.78
	S_3	19.00	19.00	23.00	20.33	54.33	54.67	57.00	55.33	68.00	70.33	71.67	70.00
	S_4	19.67	21.00	23.33	21.33	55.67	54.67	59.00	56.44	70.33	72.00	75.00	72.44
Mean		18.42	19.58	22.58		53.25	54.50	57.33		67.75	71.00	72.25	
Source of variance		S.Em.±		C. D. @ 5 %		S.Em.±		C. D. @ 5 %		S.Em.±		C. D. @ 5 %	
M		0.38		1.49		0.54		2.12		0.41		1.63	
S		0.37		1.11		0.46		1.37		0.61		1.82	
SP at same level of MP		0.64		NS		0.80		NS		1.06		NS	
MP at same or different level of SP		0.67		NS		0.88		NS		1.01		NS	

Main plot: *In situ* moisture conservation practices (C) Sub plot: Planting geometry (S)

C_1- Flat bed S_1- 45 cm × 20 cm (National check)

C_2- Compartment bunding S_2- 60 cm × 15 cm

C_3- Tied ridges S_3- 60 cm × 20 cm

S_4- 60 cm × 30 cm (UASD check)
MP- Main plot
SP- Sub plot
NS- Non-significant
DAS- Days after sowing

Table 2: Effect of different soil moisture conservation practices and planting geometry ontotal dry matter production (g/plant) at different growth stages

Treatment		Total dry matter production (g/plant)											
		30 DAS				60 DAS				At harvest			
		Moisture conservation practices (M)				Moisture conservation practices (M)				Moisture conservation practices (M)			
		C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
Spacing (S)	S_1	7.33	8.17	9.00	8.17	58.00	60.33	62.00	60.11	104.33	106.33	108.67	106.44
	S_2	7.63	8.50	9.23	8.46	58.67	61.00	62.33	60.67	104.67	107.33	108.67	106.89
	S_3	8.03	8.68	9.83	8.85	59.00	61.33	63.00	61.11	104.67	108.00	109.33	107.33
	S_4	8.60	9.00	10.50	9.37	60.33	62.00	64.33	62.22	107.00	109.00	110.00	108.67
Mean		7.90	8.59	9.64		59.00	61.17	62.92		105.17	107.67	109.17	
Source of variance		S.Em.±		C. D. @ 5 %		S.Em.±		C. D. @ 5 %		S.Em.±		C. D. @ 5 %	
M		0.19		0.75		0.53		2.09		0.35		1.38	
S		0.07		0.20		0.24		0.72		0.26		0.78	
SP at same level of MP		0.12		NS		0.42		NS		0.45		NS	
MP at same or different level of SP		0.22		NS		0.64		NS		0.53		NS	

Main plot: *In situ* moisture conservation practices (C) Sub plot: Planting geometry (S)
C_1- Flat bed
C_2- Compartment bunding
C_3- Tied ridges
S_1- 45 cm × 20 cm (National check)
S_2- 60 cm × 15 cm
S_3- 60 cm × 20 cm
S_4- 60 cm × 30 cm (UASD check)
MP- Main plot
SP- Sub plot
NS- Non-significant
DAS- Days after sowing

Table 3: Effect of different soil moisture conservation practices and planting geometry on seed weight/plant and test weight of safflower

Treatment		Seed weight per plant (g)				Test weight (100g)			
		Moisture conservation practices (M)				Moisture conservation practices (M)			
		C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
Spacing (S)	S_1	14.33	15.33	16.33	15.33	7.17	7.15	7.45	7.26
	S_2	14.33	15.67	17.00	15.66	7.33	7.33	7.53	7.40
	S_3	14.67	15.67	16.67	15.64	7.27	7.34	7.57	7.39
	S_4	15.33	16.33	17.33	16.33	7.43	7.50	7.65	7.53
Mean		14.67	15.75	16.83		7.30	7.33	7.55	
Source of variance		S.Em.±		C. D. @ 5 %		S.Em.±		C. D. @ 5 %	
M		0.25		1.00		0.01		0.07	
S		0.11		0.33		0.03		0.09	
SP at same level of MP		0.19		NS		0.05		NS	
MP at same or different level of SP		0.30		NS		0.05		NS	

Main plot: *In situ* moisture conservation practices (C) Sub plot: Planting geometry (S)
C_1- Flat bed
C_2- Compartment bunding
C_3- Tied ridges
S_1- 45 cm × 20 cm (National check)
S_2- 60 cm × 15 cm
S_3- 60 cm × 20 cm
S_4- 60 cm × 30 cm (UASD check)
MP- Main plot
SP- Sub plot
NS- Non-significant

Table 4: Effect of different soil moisture conservation practices and planting geometry on seed yield, stalk yield and harvest index of safflower

Treatment		Seed yield (kg/ha)				Stalk yield (kg/ha)				Harvest index (%)			
		Moisture conservation practices (M)				Moisture conservation practices (M)				Moisture conservation practices (M)			
		C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
Spacing (S)	S_1	1,071.67	1,070.67	1,138.00	1093	2,945.33	2,926.00	3,012.33	2,961	26.65	26.77	27.39	26.94
	S_2	898.67	913.33	1,091.00	967	2,733.67	2,754.67	2,881.33	2,789	24.72	24.67	27.44	25.61
	S_3	877.33	898.00	1,026.33	933	2,679.67	2,791.33	2,887.33	2,786	24.66	24.31	26.22	25.06
	S_4	852.00	881.67	988.67	907	2,687.67	2,769.33	2,802.33	2,753	24.07	24.15	26.07	24.76
Mean		924	940	1,061		2,761	2,810	2,895		25.02	24.98	26.78	
Source of variance		S.Em.±		C. D. @ 5 %		S.Em.±		C. D. @ 5 %		S.Em.±		C. D. @ 5 %	
M		22.58		88		20.52		80		0.33		1.33	
S		13.98		41		17.95		53		0.22		0.66	

SP at same level of MP	24.22	NS	31.10	NS	0.38	NS
MP at same or different level of SP	30.82	NS	33.86	NS	0.47	NS

Main plot: *In situ* moisture conservation practices (C) Sub plot: Planting geometry (S)
C_1- Flat bed
C_2- Compartment bunding
C_3- Tied ridges
S_1- 45 cm × 20 cm (National check)
S_2- 60 cm × 15 cm
S_3- 60 cm × 20 cm
S_4- 60 cm × 30 cm (UASD check)
MP- Main plot
SP- Sub plot
NS- Non-significant

Table 5: Effect of different soil moisture conservation practices and planting geometryon gross returns, net returns and benefit - cost (B-C) ratio of safflower

Treatment		Gross returns (₹/ha)				Net returns (₹/ha)				Benefit- Cost ratio			
		Moisture conservation practices (M)				Moisture conservation practices (M)				Moisture conservation practices (M)			
		C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
Spacing (S)	S_1	30,006	29,978	31,864	30,616	14,339	13,311	14,997	14,216	1.92	1.80	1.90	1.87
	S_2	25,162	25,573	30,548	27,094	9,495	8,906	13,681	10,694	1.61	1.53	1.86	1.67
	S_3	24,565	25,144	28,737	26,148	9,105	8,684	12,077	9,955	1.59	1.53	1.72	1.61
	S_4	23,856	24,686	27,682	25,408	8,602	8,432	11,228	9,421	1.56	1.52	1.68	1.59
Mean		25,897	26,345	29,708		10,385	9,833	12,996		1.67	1.59	1.79	
Source of variance		S.Em.±		C. D. @ 5 %		S.Em.±		C. D. @ 5 %		S.Em.±		C. D. @ 5 %	
M		632.42		2483.22		632.42		2483.22		0.03		0.13	
S		391.61		1163.54		391.61		1163.54		0.02		0.06	
SP at same level of MP		678.29		NS		678.29		NS		0.04		NS	
MP at same or different level of SP		863.15		NS		863.15		NS		0.04		NS	

Main plot: *In situ* moisture conservation practices (C) Sub plot: Planting geometry (S)
C_1- Flat bed
C_2- Compartment bunding
C_3- Tied ridges
S_1- 45 cm × 20 cm (National check)
S_2- 60 cm × 15 cm
S_3- 60 cm × 20 cm
S_4- 60 cm × 30 cm (UASD check)
MP- Main plot
SP- Sub plot
NS- Non-significant

Conclusion

The above results clearly showed that tied ridge as a moisture conservation practices and planting geometry (S1- 45 cm × 20 cm) found significantly superior in improving performance of safflower in terms of plant height, dry matter production, test weight, seed yield, stalk yield, gross returns, net returns and B–C ratio of safflower cultivation compared to other moisture conservation practices and planting geometry.

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