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Response of Non-spiny Safflower (cv NARI-6) (*Carthamus tinctorius* L.) to Planting Geometry and Fertilizer Levels under Rainfed Condition

Siddanagouda Patil, Vishwajith, P. Sheik Peer, S. M. S. Suresh, B. N. Aravindakumar, M. V. Kusuma

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Abstract Field experiment was conducted during *rabi* season 2014 at MARS, Dharwad to know the feasibility of non-spiny safflower (cv NARI-6) to planting geometry and fertilizer levels under rainfed condition. Sowing of safflower at spacing of 45 cm × 20 cm recorded significantly higher seed yield and stalk yield (S_1 : 1142 and 2878 kg/ha, respectively) over spacing of 60 cm × 30 cm (S_4: 890 and 2653 kg/ha, respectively) which was on par with spacing of 60 cm × 20 cm (S_3 :1107 and 2811 kg/ha, respectively). The treatment receiving 150% RDF recorded significantly higher seed and stalk yield (F_3: 1061 and 2860 kg/ha, respectively) which was on par with 125% RDF (F_2: 1034 and 2784 kg/ha, respectively). Among the interaction effects sowing of crop at spacing of 45 cm × 20 cm with 150% RDF application recorded significantly higher seed yield and stalk yield (S_1F_3 : 1248 and 3052 kg/ha, respectively) superior over other treatment combinations which was on par with 125% RDF with spacing of 60 cm × 20 cm (S_3F_3 : 1180 and 2982 kg/ha, respectively) and 125 % RDF with spacing of 45 cm × 20 cm (S_1F_2: 1170 and 2863 kg/ha, respectively).

Keywords Safflower (cv NARI-6), Planting geometry, Fertilizer levels.

S. Patil, Vishwajith, P. S. Peer*, S. M. S. Suresh, B. N. Aravindakumar
Department of Agronomy, College of Agriculture, Dharwad, University of Agricultural Sciences, Dharwad 580005, Karnataka, India

M. V. Kusuma
Department of Plantation, Aromatic and Medicinal Plants, KRCCH, Arabhavi, University of Horticultural Sciences, Bagalakote 591307, Karnataka, India
e-mail: sheikpeer220@gmail.com
*Correspondence

Introduction

Safflower (*Carthamus tinctorius* L.) is an annual oilseed crop belonging to Asteraceae family and its seed oil content ranges from 20 to 40 %. Safflower has been grown commercially for its edible oil and natural dye sources in the world. Since, safflower is more drought and salt tolerant than other oil seed crops, it is especially suited for dryland salty areas where other oilseed crops are difficult to grow.

In India the area under safflower is estimated around 1.78 lakh ha with annual production of 1.14 lakh tones accounting over half of the world's safflower production [1]. Karnataka and Maharashtra are the major safflower growing states, which contributes more than 90% of India's production of safflower. Safflower cultivar NARI-6 released in the year 2000 for cultivation in rainfed areas of the country produces a seed yield of 10 to 11q/ha. It contains 35% oil in its seeds. It also yields 1 to1.5 q flowers/ha.

Materials and Methods

The experiment was conducted to study the response of non-spiny safflower (cv NARI-6) to planting geometry and fertilizer levels under rainfed condition in *vertisol.* A field experiment was conducted at MARS, Dharwad during *rabi* 2014. The soil of experimental site was medium black clay soil. The experimental site was low in nitrogen (164.60 kg ha^{-1}), medium in phosphorus (35.80 kg ha^{-1}) and high in potash (368.10 kg ha^{-1}). Experiment was laid out in a randomized completely block design with factorial concept replicated thrice with different Planting geometry (S) in main factor and Fertilizer levels (F) in sub factor. The net plot size was 4.4 m × 3.6 m (15.84 m^2). Four planting geometry, vizi.) S-145 cm × 20 cm (National check) S_2-45 cm × 30 cm, S_3-60 cm × 20 cm and S_4-60 cm × 30 cm (UASD check) and three fertilizer levels F_1-100% RDF (40: 40: 12 kg N, P_2O_5, K_2O/ha), F_2 - 125% RDF (50: 50: 15 kg N, P_2O_5, K_2O/ha), F_3 - 150% RDF (60:60:18 kg N, P_2O_5, K_2O/ha) were used in the study and sowing was done as per treatments designated as S_1F_1 to S_4F_3, respectively. At one week interval, five plants $plot^{-1}$ were sampled, oven dried at 68 to 70^{0}C for complete drying then pods were separated from the plants, counted and threshed for seeds. For statistical analysis data were analyzed using analysis of variance and means were compared using critical difference at the 5% probability.

Results and Discussion

Effect of plant geometries on growth and yield safflower

Efficient interception of radiant energy by crop surface can be achieved by manipulating the plant geometry. Planting to an optimum density with appropriate plant geometry is an important consideration to improve the productivity of crop.

The seed yield was significantly influenced by different spacing. Sowing of safflower at spacing of 45 cm × 20 cm recorded significantly higher seed yield and stalk yield (S_1 : 1142 and 2878 kg/ha, respectively) over spacing of 60 cm × 30 cm (S_4: 890 and 2653 kg/ha, respectively) which was on par with spacing of 60 cm × 20 cm (S_3 : 1107 and 2811 kg/ha, respectively) (Table 1). This increase of seed yield of 28.31% over a spacing of 60 cm × 30 cm with the highest plant density was mainly attributed to the higher number of plants and heads per unit area at harvest. The variation in seed yield was due to the variation of yield components viz., number of capsules per plant, seeds per capsule, seed weight per plant and 100 seeds weight (g). Sowing of safflower at spacing of 60 cm × 30 cm recorded significantly more number of capsules per plant (S_4 : 22.50), seeds per capsules (S_4 : 28.46) and seed weight per plant (S_4 : 16.55) compared with spac-

Table 1. Seed yield, stalk yield and harvest index of safflower cv NARI-6 as influenced by different spacings and fertilizer levels. Spacings : S_1–45 × 20 cm, S_2– 45 × 30 cm, S_3–60 × 20 cm, S_4–60× 30 cm. Fertilizer levels : F_1– 100% (40:40:12 kg N, P_2O_5, K_2O per ha), F_2–125% (50:50:15 kg N, P_20_5, K_2O per ha), F_3– 150% (60:60:18 kg N, P_2O_5, K_2O per ha, NS– Non-significant.

Treatments		Seed yield (kg/ha) Spacings					Stalk yield (kg/ha) Spacings					Harvest index (%) Spacings				
		S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
Fertilizer levels	F_1	1008	953	1066	841	967	2718	2676	2652	2575	2655	27.1	26.3	28.7	24.7	26.7
	F_2	1170	984	1073	908	1034	2863	2672	2800	2801	2784	29.0	26.9	27.7	24.6	27.1
	F_3	1248	892	1180	922	1061	3052	2825	2982	2582	2860	29.0	24.0	28.4	26.3	26.9
Mean		1142	943	1107	890		2878	2724	2811	2653		28.4	25.7	28.2	25.2	

Source of variance	SEm ±	CD (p=0.05)	SEm ±	CD (p = 0.05)	SEm ±	CD (p=0.05)
Spacings	15	45	39	114	0.96	NS
Fertilizer levels	13	39	34	99	0.83	NS
Interaction (S × F)	27	78	67	198	1.67	NS

Table 2. Yield parameters of safflower cv NARI-6 as influenced by different spacings and fertilizer levels. Spacings : S_1–45 × 20 cm, S_2–45 × 30 cm, S_3–60 × 20 cm, S_4–60 × 30 cm, Fertilizer levels : F_1–100% (40:40:12 kg N, P_2O_5, K_2O per ha), F_2– 125% (50:50:15 kg N, P_2O_5, K_2O per ha), F_3–150% (60:60:18 kg N, P_2O_5, K_2O per ha). NS– Non-significant.

Treatments		Number of capsules per plant Spacings					Seed per capsules Spacings					Seed weight per plant (g) Spacings				
		S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean	S_1	S_2	S_3	S_4	Mean
Fertilizer levels	F_1	18.86	21.68	19.34	19.96	19.96	25.24	27.34	26.94	26.23	26.44	14.15	15.53	15.93	15.68	15.32
	F_2	19.57	22.40	19.73	23.12	21.21	26.34	27.66	26.02	29.34	27.34	14.74	16.04	15.14	16.89	15.70
	F_3	19.18	22.95	19.44	24.41	21.50	26.42	28.83	26.84	29.80	27.97	14.54	16.79	15.46	17.10	15.97
Mean		19.20	22.35	19.50	22.50		26.00	27.94	26.60	28.46		14.48	16.12	15.51	16.55	

Source of variance	SEm±	CD (p=0.05)	SEm ±	CD (p = 0.05)	SEm ±	CD (p=0.05)
Spacings	0.36	1.07	0.33	0.98	0.18	0.53
Fertilizer levels	0.31	0.92	0.29	0.85	0.15	0.45
Interaction (S × F)	0.63	1.85	0.58	1.71	0.31	0.91

ing of 45 cm × 20 cm (S_1 : 19.20, 26.00, 14.48 and 6.68g, respectively) (Table 2).

Significantly higher total dry matter production of safflower (S_4 : 110.37 g) was observed with spacing of 60 cm × 30 cm compared to spacing of 45 cm × 20 cm (S_1 : 107.03 g) at harvest. This higher TDMP was the cumulative effect of higher growth characters of safflower such as plant height (72.77 cm), secondary branches per plant (31.79), at harvest and leaf area index (4.35 dm^2) at 90 DAS (Table 3) compared to other spacing.

Effect of fertilizer levels on growth and yield of safflower

In the present study, the data revealed that application of 150% RDF recorded significantly higher seed and stalk yield (F_3 : 1061 and 2860 kg/ha, respectively) which was on par with 125% RDF (F_2 : 1034 and 2784 kg/ha, respectively). Significantly lower seed and stalk yield (F_1 : 967 and 2655 kg/ha, respectively) was recorded by the 100% RDF (Table 1). The increase in seed and stalk yield with 150% RDF was to the tune of 9.7 and 7.7% respectively over 100% RDF which has a close relation with respect to number of capitullum per plant.

Among the fertilizer levels 150% RDF application recorded significantly higher number of capsules, number of seeds per capsules and seed weight per plant (F_3 : 21.50, 27.97 and 15.97 g, respectively) which was on par with 125% RDF (F_2 : 21.21, 27.34 and 15.70 g, respectively) (Table 2). Significantly lowest number of capsules, number of seeds per capsules (F_1 : 19.96, 26.44 and 15.32 g, respectively) was noticed by the 100% RDF application. The increase in number of capsules per plant might be due to higher dry matter production and translocation of more photosynthates to sink resulting in more number of seeds per capsules.

Application 150% RDF recorded significantly higher total dry matter production (F_3 : 109.76 g) which was on par with 125% RDF (F_2 : 108.84 g). Significantly lower total dry matter production (F_1 : 106.52 g) was recorded by the 100% RDF. Dry matter production and its accumulation in reproductive parts are closely related to leaf area index. In the present study, increase in the fertilizer level lead to significantly higher leaf area index at different growth stages. At 90 DAS, significantly higher leaf area index was recorded at 150% RDF as compared to 100% RDF (Table 3). This results clearly indicates the importance of nutrients for higher seed production in safflower. The optimum availability of nutrients has influenced the growth and development of better root system, which helped in better uptake of nutrients. Further, it improved the rate of photosynthesis, dry matter accumulation and its translocation to reproductive parts

Table 3. Growth parameter of safflower cv NARI-6 as influenced by different spacings and fertilizer levels. Spacings : S_1–45 × 20 cm, S_2–45 × 30 cm, S_3–60 × 20 cm, S_4–60 × 30 cm, Fertilizer levels : F_1– 100% (40:40:12 kg N, P_2O_5, K_2O per ha), F_2–125% (50:50:15 kg N, P_2O_5, K_2O per ha), F_3–150% (60:60:18 kg N, P_2O_5, K_2O per ha), NS– Non-significant.

Treatments		Plant height (cm) at 90 DAS Spacings S_1	S_2	S_3	S_4	Mean	Secondary branches per plant Spacings S_1	S_2	S_3	S_4	Mean
	F_1	67.01	71.64	67.61	69.11	68.84	30.00	30.40	31.17	30.93	30.81
Fertilizer levels	F_2	68.45	71.49	70.98	74.31	71.31	31.17	31.60	31.33	32.07	31.54
	F_3	71.07	72.42	69.02	74.88	71.85	31.31	31.97	30.76	32.37	31.60
Mean		68.84	71.85	69.20	72.77		30.96	31.43	31.08	31.79	

Source of variance	SEm ±	CD (p =0.05)	SEm ±	CD (p = 0.05)
Spacings	0.54	1.60	0.13	0.40
Fertilizer levels	0.47	1.39	0.11	0.34
Interaction (S × F)	0.95	2.78	0.23	0.69

Table 3. Continued.

Treatments		Leaf area index (dm^2) at 90 DAS Spacings S_1	S_2	S_3	S_4	Mean	Total dry matter (g/plant) at harvest Spacings S_1	S_2	S_3	S_3	Mean
Fertilizer levels	F_1	4.06	2.90	3.26	2.11	3.08	104.65	107.7	107.11	106.58	106.52
	F_2	4.47	2.99	3.28	2.23	3.27	108.33	109.1	106.44	111.44	108.84
	F_3	4.52	3.07	3.14	2.34	3.27	108.10	110.9	106.93	113.08	109.76
Mean		4.35	2.99	3.23	2.26		107.03	106.2	104.83	110.37	

Source of variance	SEm ±	CD (p=0.05)	SEm ±	CD (p=0.05)
Spacings	0.01	0.04	0.45	1.33
Fertilizer levels	0.01	0.03	0.39	1.15
Interaction (S×F)	0.02	0.07	0.79	2.31

as indicated by higher values of growth and yield components that resulted in better seed yield of safflower by Babak et al. [2] and Shakeri et al. [3].

Interaction effect of spacing and fertilizer levels on growth and yield of mungbean

Interaction of plant geometries and fertilizer levels plays a major role in increasing the production of oil seeds in general and safflower in particular. Among the interaction effects sowing of crop at spacing of 45 cm × 20 cm with 150% RDF application recorded significantly higher seed yield and stalk yield (S_1F_3: 1248 and 3052 kg/ha, respectively) over other treatment combinations which was on par with 125% RDF with spacing of 60 cm × 20 cm (S_3F_3 : 1180 and 2982 kg/ha, respectively) and 125% RDF with spacing of 45 cm × 20 cm (S_1F_2 : 11.70 and 2863 kg/ha, respectively) (Table 3). Significantly lowest seed yield (S_4F_1: 841 and 2575 kg/ha, respectively) was recorded by 100% RDF with spacing of 60 cm × 30 cm. These results are revealed with Saad Ahmed and Mohammed AL-Doori [4].

Higher seed yield of safflower is closely related to number of capsules per plant, seeds per capsules and seed weight per plant. Significantly higher capsules per plant (S_4F_3 : 24.41), seeds per capsules (S_4F_3: 29.80) and seed weight per plant (S_4F_3 : 17.10) was recorded as a treatment combination of 60 cm × 30 cm

plant geometry with fertilizer level of 150% RDF compared to other treatment combinations which might be due to optimum spacing and adequate fertilizer availability along with growth which helped in arresting excessive vegetative growth (Table 2).

Application of 150% RDF with spacing of 60 cm × 30 cm was recorded significantly higher total dry matter production at harvest (S_4F_3 : 113.08 g) and it was on par with 125% RDF with spacing of 60 cm × 30 cm (S_4F_2 : 111.44 g) and 150% RDF with spacing of 45 cm × 30 cm (S_2F_3 : 110.91 g). This higher TDMP was the cumulative effect of higher growth characters of safflower such as plant height (S_4F_3 : 74.88 cm), higher number of primary branches per plant (S_4F_3 : 16.17) and number of secondary branches per plant (S_4F_3 : 32.37), at harvest. The results are in line with Jose et al. [5].

From the present investigation it can be concluded that sowing of safflower crop at plant geometry of 45 cm × 20 cm with fertilizer level of 150% RDF (60:60: 18 kg N, P_2O_5, K_2O/ha) to get maximum seed yield (1248 kg/ha) and net returns (Rs 18295/ha), which is on par with 125% (50:50:15 kg N, P_2O_5, K_2O/ha). Hence, spacing of 45 cm × 20 cm with 125% RDF (50:50:15 kg N, P_2O_5, K_2O/ha) is found profitable in Vertisols of Northern Transitional Zone of Karnataka.

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