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Effects of Dates of Sowing, Spacing and Seed Rate on Flowering, Seed Yield and Quality of Sunnhemp

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ABSTRACT Sowing of sunnhemp during 2nd fortnight of August recorded significantly higher number of pods per plant (46.18), seeds per pod (10.02) and seed yield per ha (836.8 kg) as compared to 1st fortnight of September. Row spacing of 30 cm recorded significantly higher number of pods per plant (42.62), seeds per pod (9.82) and seed yield per ha (770.1 kg) over wider row spacing of 45 cm. The seed rates of 15 kg per ha (753.5 kg/ha) and 20 kg per ha (680.2 kg/ha). Early sowing, closer row spacing and lower seed rate delayed the flowering.

Key words: Sunnhemp, dates of sowing, seed rate, row spacing

Green manuring with sunnhemp (Crotalaria juncea L.) improves the soil fertility by adding large quantity of organic matter (30 t ha^{-1}) and nitrogen (134 kg ha^{-1}) to the soil. The non-availability of good quality seed is one of the constraints in popularizing the practice of green manuring with sunnhemp. Hence, making available the quality seeds of this crop at reasonable price is need of the hour. Suitable techniques are to be developed for each agro-climatic situation, as the flowering behaviour and seed setting is influenced by seasonal conditions. The suitable time of sowing is most important for obtaining higher yields, as it provides optimum growing conditions. As the sunlight and plant density have got close relationship with the crop yield, the number of plants per unit area is one of the prime considerations to obtain higher seed yield. This depends upon the nature of the crop, growth habit, branching and the environmental conditions so that excessive plant competition will reduce the overall efficiency of the crop. Row spacing is one of the important factors in achieving optimum level of plant density. For optimizing the seed rate, the soil moisture and nutrient status are considered most important. Under sufficient soil moisture and nutrient, the optimum seed rate per unit area is closely related to morphological characteristics of the plant. Variation in the seed rate has been found to affect the growth and dry matter accumulation due to differential availability of light, moisture and nutrients. Hence, the present study was undertaken to find out the suitable date of sowing, spacing and seed rate for production of sunnhemp seeds.

MATERIALS AND METHODS

A field experiment was carried out at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad during kharif 2001 and laboratory studies were conducted at National Seed Project Laboratory. The experiment was conducted in split plot design with four dates of sowing viz., second fortnight of July (D_1), first fortnight (FN) of August (D_2), second fortnight of August (D_3) and first fortnight of September (D_4) as main plots, the two row spacings of 30 cm (S_1) and 45 cm (S_2) and three seed rates, 10 kg. (SR_1), 15 kg. (SR_2) and 20 kg. (SR_3) per ha, were the sub and sub-sub plots, respectively.

A fertilizer dose of 10:20:20 kg. NPK per ha. was applied as basal dose. The seeds were hand dibbled. Proper care was taken to raise the healthy

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crop. The observations on growth, yield and yield parameters were recorded. The germination test was carried out as per ISTA procedure [1]. The shoot and root length were recorded on final count day (14th day). The vigour index was computed by multiplying germination percentage with seedling length [2].

RESULTS AND DISCUSSION

Effects of dates of sowing

Significant influence of sowing dates on yield, yield parameters and flowering was observed. The number of pods per plant (46.18) and seeds per pod (10.02) recorded with the crop sown on 2nd FN of August were significantly higher over other dates of sowing (Table 1). Either early sowing (IInd FN July) or late sowing (1st FN September) reduced these parameters significantly. Significantly higher seed yield per plant was recorded with 2nd FN of August sowing, whereas, the crop sown during 1st FN of September recorded significantly lower seed yield per plant (Table 1). The increase in seed yield per plant was due to increased number of pods per plant and better seed filling [3]. The seed weight was better with the 2nd FN of August sowing. The 1000-seed weight recorded with this sowing was significantly higher (44.81 g) compared to other dates of sowing (Table 2). The availability of favourable conditions during seed filling stage might have resulted in translocation of nutrients to the seed, leading to better seed development [3, 4].

Sunnhemp crop sown during August 2nd FN recorded significantly higher seed yield (836.8 kg ha^{-1}), which was 8.7 and 5.1 per cent higher as compared to early sowing during 2nd FN of July (769.7 kg ha^{-1}) and 2nd FN of August (795.5 kg ha^{-1}). The delay in sowing by another fortnight i.e., 1st FN of September recorded significantly lower seed yield (550.2 kg ha^{-1}) compared to early sowing (Table 1). The reduction in seed yield was to the tune of 60.8 per cent compared to 2nd FN of August. The highest harvest index (0.198) was observed in the crop sown on 2nd FN of August over other dates of sowing, which was mainly due to higher seed yield ha^{-1} (Table 2).

The seed germination percentage did not vary significantly with dates of sowing (Table 3). However, vigour index differed significantly due to dates of sowing (Table 3). The crop sown during 2nd FN of August recorded significantly higher vigour index (2962) as compared to other dates of sowing (Table 2). This might be due to better seed filling that resulted into higher seed weight. The bolder seeds with higher food reserves might have resulted in better expression of the seed vigour [5].

The days to flowering varied significantly with the dates of sowing. The number of days taken to 50 per cent flowering was more in the crop sown early. The delayed sowings resulted in early flowering (Table 2). The July 2nd FN sown crop took more number of days for 50 per cent flowering compared to September 1st FN sowing. The delayed flowering with the early sown crop might be due to prolonged vegetative phase of the crop growth [6].

Effects of row spacing

The yielding ability of a crop is the reflection of yield attributing character i.e., number of pods per plant, which were significantly higher at closer row spacing (42.62) compared to wider row spacing of 45 cm (Table 1). The number of seeds per pod recorded were also significantly higher at 30 cm row spacing (9.82) compared to wider row spacing of 45 cm (9.57).

Significantly higher 1000-seed weight (44.14 g) and harvest index (0.189) were recorded at closer row spacing of 30 cm as compared to wider row spacing (42.35 g and 0.177, respectively) (Table 2). This might be due to more plant competition and restriction of intra row spacing for better utilization of nutrients, moisture and solar radiation. Though the inter row spacing was higher at 45 cm, competition for moisture, nutrients, etc., was more with the wider row spacing because of lesser intra row spacing.

The closer row spacing of 30 cm recorded significantly higher seed yield per plant (18.36 g) and per ha (770.1 kg) as compared to wider row spacing of 45 cm (16.57 g and 706.0 kg, respectively) (Table 1). The increase in seed yield was to the tune of 9.1 per cent over wider row spacing. The 30 cm row spacing provided better cropping geometry with respect to utilization of resources (viz., light, soil moisture, nutrient, etc.). The

Table 1. Number of pods/plant and no. of seeds/pod, seed yield/plant (g) and seed yield/ha (kg) as influenced by dates of sowing, spacing and seed rate

Treatment		Number of pods per plant					Number of seeds per pod					Seed yield/plant (g)					Seed yield/ha (kg)				
		D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean
Spacing - 30 cm (S_1)	SR_1	45.27	51.00	54.47	38.27	47.25	9.93	10.43	10.47	9.83	10.21	21.17	21.86	27.40	16.78	21.98	821.0	848.0	872.0	575.0	779.0
	SR_2	42.53	45.27	49.80	35.53	43.28	9.73	9.73	9.90	9.50	9.73	17.20	17.04	23.69	13.79	17.93	854.0	854.3	950.0	597.0	813.0
	SR_3	36.47	39.53	41.53	31.80	37.33	9.17	9.47	9.73	9.43	9.53	13.34	18.65	22.91	13.32	17.05	794.3	737.3	778.3	560.3	717.6
	Mean	41.42	45.27	48.60	35.20	**42.62**	9.61	9.88	10.03	9.59	**9.82**	17.42	19.18	24.67	13.56	**18.36**	823.1	813.2	966.8	577.4	**770.1**
Spacing - 45 cm (S_2)	SR_1	44.47	46.80	46.20	35.27	43.68	9.60	9.33	10.27	9.57	9.85	17.86	17.63	24.39	13.56	18.36	712.3	854.3	844.3	603.0	728.0
	SR_2	40.40	42.87	43.20	32.33	39.70	9.47	9.53	10.13	9.40	9.61	16.26	16.59	22.78	12.51	17.03	773.0	840.3	858.7	517.0	747.2
	SR_3	37.47	36.93	39.87	31.67	36.48	9.06	9.33	9.60	9.03	9.33	13.76	14.28	17.40	11.81	14.31	663.7	741.0	717.3	449.0	642.7
	Mean	40.87	42.20	43.76	33.09	**39.96**	9.38	9.60	10.00	9.33	**9.57**	15.96	16.17	21.52	12.63	**16.57**	716.3	777.9	806.8	523.0	**706.0**
Seed rate (means) SR	SR_1	44.87	48.90	51.53	36.77	45.47	9.77	10.18	10.37	9.70	10.00	19.79	19.44	25.90	15.17	20.15	766.7	800.2	858.2	589.0	753.5
	SR_2	41.47	44.07	46.50	33.90	41.49	9.60	9.63	10.02	9.45	9.73	16.72	16.82	23.23	13.15	17.48	813.0	847.3	904.8	557.0	780.5
	SR_3	36.97	38.23	40.70	31.70	36.91	9.11	9.40	9.67	9.23	9.33	13.55	16.46	20.15	12.37	15.68	729.0	739.2	747.8	504.7	680.2
	Mean	41.10	43.73	46.18	34.10	**41.29**	9.49	9.74	10.02	9.46	**9.76**	16.68	17.68	23.63	13.63	**17.77**	769.7	795.5	836.8	550.2	**738.1**

For comparing means of	S.Em.±	CD (0.05)	S.Em.±	CD (0.05)	S.Em.±	CD (0.05)	S.Em.±	CD (0.05)
Date of sowing (D)	1.12	3.88	0.05	0.19	0.39	1.35	12.7	44.1
Row spacing (S)	0.60	1.97	0.05	0.16	0.13	0.41	8.6	27.4
Seed rate (SR)	0.42	1.21	0.11	0.31	0.31	0.90	10.2	29.3
DxS	1.20	NS	0.10	NS	0.25	0.82	17.1	NS
DxSR	0.84	2.41	0.22	NS	0.62	1.79	20.3	NS
SxSR	0.59	1.70	0.15	NS	0.44	1.36	14.4	NS
D x S x SR	1.18	NS	0.30	NS	0.88	NS	28.8	NS

D_1 -2nd fortnight of July; D_2 -1st fortnight of August; D_3 -2nd fortnight of August; D_4 -1st fortnight of September; SR_1 - 10 kg ha^{-1}; SR_2 - 15 kg ha^{-1}; SR_3 - 20 kg ha^{-1}; NS - Non-significant

Table 2. Harvest index, 1000-seed weight (g), vigour index and days to 50% flowering as influenced by dates of sowing, spacing and seed rate

Treatment		Harvest index					1000-seed weight (g)					Vigour index					Days to 50% flowering				
		D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean
Spacing - 30 cm (S_1)	SR_1	0.202	0.205	0.215	0.165	0.197	45.66	44.15	48.50	44.07	45.59	2159	2666	2980	2738	2786	49.0	49.0	48.3	47.0	48.3
	SR_2	0.201	0.202	0.213	0.164	0.195	44.44	43.78	46.82	41.81	44.26	2666	2851	2968	2601	2772	48.0	47.0	46.7	46.3	47.0
	SR_3	0.185	0.182	0.178	0.153	0.174	44.18	41.44	43.97	40.68	42.57	2722	2741	2779	2657	2730	45.7	45.0	45.3	44.3	45.1
	Mean	0.196	0.196	0.202	0.161	**0.189**	42.55	44.01	43.74	42.47	**44.14**	2716	2753	2916	2665	**2762**	47.6	47.0	46.8	45.9	**46.8**
Spacing - 45 cm (S_2)	SR_1	0.183	0.192	0.207	0.174	0.189	42.55	44.01	43.74	42.47	43.19	2718	2722	2856	2877	2793	49.3	48.3	47.7	44.0	47.3
	SR_2	0.187	0.197	0.200	0.150	0.184	42.13	43.18	43.48	41.38	42.54	2698	2775	2922	2746	2785	47.0	47.0	45.3	43.7	45.7
	SR_3	0.161	0.176	0.171	0.130	0.160	41.60	41.29	42.36	40.02	41.32	2652	2738	2890	2601	2720	44.7	44.3	43.7	44.0	44.2
	Mean	0.177	0.188	0.193	0.151	**0.177**	43.19	42.54	41.32	42.35	**42.35**	2689	2745	2889	2741	**2766**	47.0	46.6	45.6	43.9	**45.7**
Seed rate (means) SR	SR_1	0.192	0.198	0.211	0.179	0.193	44.10	44.08	46.12	43.27	44.39	2738	2694	2918	2808	2789	49.2	48.7	48.0	45.5	47.8
	SR_2	0.194	0.200	0.207	0.157	0.199	43.38	43.48	45.15	41.59	43.40	2682	2813	2945	2673	2778	47.5	47.0	46.0	45.0	46.4
	SR_3	0.173	0.178	0.175	0.142	0.167	42.89	41.37	43.16	40.35	41.94	2687	2739	2844	2627	2725	45.2	44.7	44.5	44.2	44.6
	Mean	0.186	0.192	0.198	0.156	**0.183**	43.46	42.98	44.81	41.74	**43.25**	2702	2748	2962	2703	**2764**	47.3	46.8	46.2	44.9	**46.3**

For comparing means of	Harvest index		1000-seed weight (g)		Vigour index		Days to 50% flowering	
	S.Em.±	CD (0.05)	S.Em.±	CD (0.05)	S.Em.±	CD (0.05)	S.Em.±	CD (0.05)
Date of sowing (D)	0.051	0.176	0.51	1.76	30	96.8	0.3	1.1
Row spacing (S)	0.018	0.058	0.55	1.78	24	NS	0.2	0.5
Seed rate (SR)	0.030	0.087	0.45	1.30	30	NS	0.2	0.6
DxS	0.036	NS	1.09	NS	48	NS	0.3	NS
DxSR	0.061	NS	0.90	NS	59	NS	0.4	NS
SxSR	0.042	NS	0.63	NS	42	NS	0.3	NS
D x S x SR	0.086	NS	1.23	NS	84	NS	0.6	NS

D_1 - 2nd fortnight of July; D_2 - 1st fortnight of August; D_3 - 2nd fortnight of August; D_4 -1st fortnight of September; SR_1 -10 kg ha^{-1}; SR_2 -15 kg ha^{-1}; SR_3 -20 kg ha^{-1}; NS - Non-significant

reduction in seed yield of sunnhemp under wider row spacing could be mainly attributed to restricted intra row spacing, which resulted in restriction of space for utilization of nutrients, moisture and solar radiation [7]. The seed quality parameters did not vary significantly with the row spacings.

The days to 50 per cent flowering varied with row spacing (Table 2). Closer row spacing of 30 cm took significantly more number of days for 50 per cent flowering compared to wider row spacing of 45 cm.

Effects of seed rate

Under optimum growth conditions, the optimum seed rate per unit area is closely related to growth yield and yield components. The number of pods per plant and seeds per pod were significantly higher (Table 1), at a lower seed rate of 10 kg ha^{-1} as compared to 15 and 20 kg ha^{-1}. The seed yield $plant^{-1}$ was also significantly higher at 10 kg ha^{-1} seed rate (20.15 g) as compared to 15 and 20 kg ha^{-1} (Table 1). The 1000-seed weight was significantly lower with higher seed rate of 20 kg ha^{-1} (Table 2).

The harvest index was significantly higher at the seed rate of 15 kg ha^{-1} (0.199) compared to 20 kg seeds ha^{-1} (0.167) (Table 2). The lower harvest index at 20 kg seeds ha^{-1} was mainly due to intense competition between plants for resources at the time of seed development, which resulted in poor seed filling and seed set compared to 10 kg seed rate ha^{-1}, wherein, better seed set and good seed filling was associated with less inter plant competition.

Significantly higher seed yield ha^{-1} (780.5 kg ha^{-1}) was obtained with a seed rate of 15 kg ha^{-1} followed by 10 kg ha^{-1}, which were on par with each other (Table 1). The seed yield per plant was higher with the seed rate of 10 kg ha^{-1} (20.15 g) because of better yield components at lower seed rate, which might be due to lesser competition between plants for resources such as, space, solar radiation, soil moisture and nutrients. The seed rate of 15 kg ha^{-1} recorded 3.5 per cent higher seed yield compared to seed rate of 10 kg ha^{-1}, whereas, the increase in seed rate from 15 to 20 kg ha^{-1} reduced the yield to the extent of 12.9 per cent. The higher number of plants per ha at a seed rate of 15 kg ha^{-1} compared to 10 kg ha^{-1}, resulted in higher seed yield ha^{-1}.

Table 3. Germination (%) as influenced by dates of sowing, spacing and seed rate

Treatment		Number of pods per plant				
		D_1	D_2	D_3	D_4	Mean
Spacing-30 cm (S_1)	SR_1	73.9 (59.0)	74.0 (59.3)	74.7 (59.8)	74.3 (59.6)	74.1 (58.9)
	SR_2	73.5 (59.0)	74.3 (59.6)	75.0 (60.0)	71.7 (57.8)	73.6 (59.2)
	SR_3	73.0 (58.7)	73.3 (58.9)	75.0 (59.8)	72.6 (59.2)	73.5 (60.0)
	Mean	73.3 (59.4)	73.8 (59.8)	74.9 (59.2)	73.0 (59.2)	**73.7 (59.8)**
Spacing-45 cm (S_2)	SR_1	74.3 (59.5)	74.3 (59.5)	74.0 (59.3)	74.8 (59.8)	74.3 (59.4)
	SR_2	73.3 (58.8)	73.7 (59.5)	74.0 (50.0)	72.7 (58.5)	73.7 (59.4)
	SR_3	74.0 (59.3)	74.0 (59.2)	74.5 (59.4)	74.0 (59.3)	74.1 (59.7)
	Mean	73.8 (59.5)	74.0 (59.1)	74.5 (59.4)	73.8 (59.0)	**74.0 (59.2)**
Seed rate (means) SR	SR_1	73.9 (59.5)	74.1 (59.3)	74.4 (59.5)	74.5 (59.0)	74.3 (59.5)
	SR_2	73.4 (59.2)	74.0 (60.0)	75.0 (58.2)	72.3 (58.5)	73.7 (59.1)
	SR_3	73.5 (59.3)	73.6 (59.6)	74.7 (59.3)	73.4 (59.3)	73.8 (59.3)
	Mean	73.6 (59.1)	73.9 (59.3)	74.7 (59.8)	73.4 (59.1)	**73.6 (59.3)**

For comparing means of	S.Em.±	CD (0.05)
Date of sowing (D)	0.4 (0.2)	NS
Row spacing (S)	0.3 (0.2)	NS
Seed rate (SR)	0.4 (0.2)	NS
DxS	0.6 (0.3)	NS
DxSR	0.7 (0.5)	NS
SxSR	0.5 (0.3)	NS
D x S x SR	1.1 (0.7)	NS

D_1 - 2nd fortnight of July; D_2 - 1st fortnight of August; D_3 - 2nd fortnight of August; D_4 - 1st fortnight of September; SR_1 - 10 kg ha^{-1}; SR_2 - 15 kg ha^{-1}; SR_3 - 20 kg ha^{-1}; NS - Non-significant

The seed rate of 10 kg $plant^{-1}$ showed numerically higher values for germination percentage (74.3%) and vigour index (2789). This might be due to less plant to plant competition and accumulation of higher food reserves, which resulted in better quality seeds.

The days to flowering varied with the seed rates. The higher seed rate resulted in early flowering (Table 2). The early flowering with the higher seed rate might be due to creation of abiotic stress because of more number of plants per unit area, which compete among themselves for moisture, nutrients, etc. This might have resulted in early transformation of vegetative phase into reproductive phase [6].

In conclusion, under Dharwad conditions, higher seed yield of sunnhemp can be obtained by sowing the sunnhemp crop during 2nd FN of August with a seed rate of 15 kg ha^{-1} at a row spacing of 30 cm.

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