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Optimization of Plant Geometry and NPK Levels for Seed and Fibre Yield Maximization in Sunnhemp [*Crotalaria juncea* (L.)] Genotypes

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A field experiment was conducted during *Kharif* 2017 to study the response of Sunnhemp varieties (SH 4 and SUIN 053) to two plant geometry (30 x 15 cm and 45 x 15 cm) and three NPK levels (20:40:40, 20:60:60 and 20:80:80 kg N, P_2O_5, K_2O ha^{-1}). The results revealed that the variety SH 4 produced higher seed yield as a result of higher values of growth and yield attributes except the number of secondary branches per plant and basal diameter. However the fibre yield was higher with the variety SUIN 053. Though higher yield attributes were observed under a wider spacing of 45 x 15 cm, the seed and fibre yield were highest with a closer spacing of 30 x15 cm by virtue of higher plant density per unit area. A fertilizer dose of 20:80:80 kg ha^{-1} produced higher seed yield of 1420 kg ha^{-1}. However the net return and BCR obtained indicated that application of 20:60:60 kg N, P_2O_5, K_2O ha^{-1} was economical.

Key words: Sunnhemp, Spacing, Seed yield, Fibre production

Sunnhemp (*Crotalaria juncea* L.,) is an important multipurpose leguminous crop grown for fibre, green manure and fodder purposes (Chaudhary *et al.,* 2012). The amount of organic matter added by sunnhemp to the soil by green manuring varied from 12-25 tons ha^{-1}depending on the time of incorporation. If it is incorporated at 50-60 days stage on an average of 15 tons green matter is added, which provided an amount of 50-75 kg N, 15-20 kg P_2O_5 and 40-65 kg K_2O ha^{-1} (Panse *et al.,* 1965). In addition, 50-60 kg N ha^{-1} is added through root nodules. Apart from sunnhemp as a green manure crop, it has the potential for fibre production. The fibre of sunnhemp has high cellulose, low lignin, greater tensile strength, more durable than jute and negligible ash content (Chaudhary *et al*., 2013). It is gaining importance because of increasing demand for a specific grade fibre required for manufacture of tissue paper and paper for currency (Kumar *et al.,* 2005).

The major limiting factor in adoption of green manuring practice and fibre production is the availability of quality seed, lack of suitable agronomic practices and high cost of the seed material involved. Among the constraints, unfortunately non-availability of sunnhemp seeds at the appropriate time is a great problem for future expansion of this crop (Palaniappan and Bhudar, 1992).

Hence in order to meet the demand for sunnhemp seeds, development of agro techinique such as optimization of plant geometry and nutrient requirement is very much needed at this stage to maximize the seed production per unit area. Spacing is one of the factors affecting seed and fibre yield of sunnhemp. It influences growth rate and crop yield as a result of inter plant competition for different inputs needed for growth and development. Nutrient management is another important factor that influences seed and fibre yield. Response of applied nitrogen has not been very much pronounced on the fibre yield, while application of phosphorus resulted in production of more fibre coupled with more bacterial activities in fixation of nitrogen (Maitra *et al.,* 2008). Very meager information on spacing along with nutrient management is available in sunnhemp. Keeping these points in view, the present investigation was carried out to study the effect of spacing and nutrient management practices on seed and fibre yield of sunnhemp.

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Material and Methods

The experiment was conducted at Central Farm of Tamil Nadu Rice Research Institute, Aduthurai during July to November, 2017. The experimental site located in the Cauvery delta agro climatic zone of Tamil Nadu at 1l^o N latitude, 79^o E longitude and at an altitude of 19.5 m above mean sea level. Soil of the experimental site was sandy loam with a pH 8.0, low in organic carbon (0.11 %) and medium in available nitrogen (282 kg ha^{-1}), high in available phosphorus (37 kg ha^{-1}) and high in available potassium (381 kg ha^{-1}). The experiment was laid out in split plot design keeping varieties and spacing treatments in main plots and fertilizer levels in sub plots with three replications. The experiment comprised of two varieties (SH 4 and SUIN 053), two levels of spacing (30 cm × 15 cm and 45 cm × 15 cm) and three levels of NPK (20:40:40, 20:60:60 and 20:80:80 kg N, P_2O_5, K_2O ha^{-1}) constituting 12 treatment combinations. The sunnhemp varieties were sown manually in plot size of 4.5 × 4.5 m. The total annual rainfall received during the cropping period was 890.6 mm. The crop was gap filled 5 days after sowing to maintain plant to plant spacing according to treatments. Remaining package of practices was adopted as per recommendation. The crop was harvested at maturity at the age of 120 days. The plant based data comprised of number of pods plant^{-1}, number of seeds pod^{-1} and 100 seed weight. Plot based data included seed, fibre and stalk yield. The cost of cultivation, gross return, net return and benefit cost ratio were calculated on the basis of prevailing market price of different inputs and outputs. The observed data on crops were statistically analyzed based on the procedure given by Gomez and Gomez *et al.* (1984).

Results and Discussion

A. Optimization of Plant Geometry and NPK levels for Seed Yield Maximization in Sunnhemp

Performance of varieties

Varieties exerted a profound influence on yield attributes (Table 2). The two varieties differed significantly for the number of matured pods plant^{-1}, number of seeds pod^{-1} and 100 seed weight. Between the varieties, SH 4 produced more number of pods plant^{-1} (63.4), seeds pod^{-1} (10.4) and 100 seed weight (29.4 g) as compared to SUIN 053. The differential behavior of varieties could be explained by the variation in their genetic makeup. As a result

Table 1. Effect of varieties, spacing and fertilizer levels on Number of secondary branche plant^{-1}, Dry matter production (g .plant^{-1}), number of pods/ plant^{-1}of sunnhemp

Treatment		Number of secondary branches plant^{-1}				Dry matter production (g plant^{-1})				Number of pods plant^{-1}			
		F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
V_1	S_1	15.4	18.1	18.8	17.4	27	29	29.6	28.5	54.2	61.5	63.8	59.8
	S_2	18.4	21.5	22.1	20.7	35.5	38.5	39.3	37.7	60.8	68.6	71.3	66.9
	Mean	16.9	19.8	20.4	19	31.2	33.7	34.4	33.1	57.5	65	67.5	63.4
V_2	S_1	13.8	15.3	16.1	15.1	22	23.7	24.5	23.4	47.2	52.7	54.9	51.6
	S_2	15.4	17.3	17.9	16.9	28.9	31.9	32.9	31.2	49.9	56.1	58.7	54.9
	Mean	14.6	16.3	17	16	25.4	27.8	28.7	27.3	48.6	54.4	56.8	53.3
		15.7	18	18.7		28.3	30.7	31.6		53	59.7	62.2	
Mean	S_1	14.6	16.7	17.4	16.2	24.5	26.3	27	26	50.7	57.1	59.3	55.7
	S_2	16.9	19.4	20	18.8	32.2	35.2	36.1	34.5	55.4	62.4	65	60.9

	Number of secondary branches plant^{-1}		Dry matter production (g plant^{-1})		Number of pods plant^{-1}	
	SEd	CD (0.05)	SEd	CD (0.05)	SEd	CD (0.05)
V	0.3	0.8	0.5	1.3	1.1	2.7
S	0.3	0.8	0.5	1.3	1.1	2.7
F	0.3	0.7	0.5	1.1	1	2.2
V x S	0.5	NS	0.8	NS	1.5	NS
S x F	0.5	NS	0.8	NS	1.6	NS
V x F	0.5	NS	0.8	NS	1.6	NS
F x S	0.4	NS	0.8	NS	1.5	NS
F x V	0.4	NS	0.8	NS	1.5	NS

V_1–SH4, V_2 - SUIN053, S_1 – 30 cm x 15 cm, S_2 – 45 cm x 15 cm, F_1 – 20:40:40 N, P_2O_5 & K_2O kg /ha, F_2 – 20:60:60 N, P_2O_5 & K_2O kg /ha, F_3 – 20:80:80 N, P_2O_5 & K_2O kg/ ha.

varieties differed significantly for yield. The variety SH 4 registered a seed yield of 1207 kg ha^{-1} which was 26.1 per cent higher than the variety SUIN 053.

Influence of spacing

The results revealed that difference in number of pods plant^{-1}, number of seeds pod^{-1} and 100 seed weight between the two plant geometry was significant (Table 1 & 2). Crop sown at a spacing of 45 cm x 15 cm produced more number of pods plant^{-1} (60.9), number of seeds pod^{-1} (10.0) and higher 100 seed weight (29.1 g) as compared to closer spacing of 30 cm x15 cm. The augmentation in number of pods plant^{-1} under the impact of wider spacing 45 cm x 15 cm might be due to higher number of secondary branches plant^{-1}. These findings are in line with the results by Shastri *et al.,* (2007) in sunnhemp. Though the yield attributes were higher with the wider spacing of 45 cm x 15 cm, seed yield was significantly higher with 30 cm x 15 cm due to variation in the plant density unit area^{-1}. Between the two spacings studied, closer spacing of 30 x 15 cm registered significantly higher seed yield of 1163 kg ha^{-1} which was 16.1 per cent higher than the wider spacing of 45 cm x 15 cm. The enhancement in yield attributes under wider spacing failed to recompense for lower number of plants unit area^{-1} under this spacing. Although at closer spacing plants became sub marginal and produced yield below their potentiality but the aggregate effect of enormous number of sub marginal plants augmented the total yield ha^{-1}. These results are in corroboration with the findings of Ulemale and Shivankar (2003).

Influence of NPK levels

Among the different fertilizer levels, application of 20:80:80 N, P_2O_5, K_2O ha^{-1} resulted in more number of pods plant^{-1}, number of seeds pod^{-1}, higher 100 seed weight. However it was comparable with fertilizer dose of 20:60:60 kg N, P_2O_5, K_2O ha^{-1}. Application of the major nutrients might have supplied the

Table 2. Effect of varieties, spacing and fertilizer levels on the yield attributes of sunnhemp

Treatment		Number of seeds pod^{-1}				100 seed weight (g)			
		F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
V_1	S_1	8.5	9.4	10.1	9.3	27.1	28.2	28.5	27.9
	S_2	9.8	11.9	12.4	11.4	29.6	31.4	31.7	30.9
	Mean	9.2	10.7	11.3	10.4	28.4	29.8	30.1	29.4
V_2	S_1	6.9	8.2	8.6	7.9	24	26.9	27.4	26.1
	S_2	7.9	8.7	9	8.5	26.2	27.5	27.9	27.2
	Mean	7.4	8.5	8.8	8.2	25.1	27.2	27.7	26.7
		8.3	9.6	10		26.7	28.5	28.9	
Mean	S_1	7.7	8.8	9.4	8.6	25.6	27.6	28	27
	S_2	8.9	10.3	10.7	10	27.9	29.5	29.8	29.1

	Number of seeds pod^{-1}		100 seed weight (g)	
	SEd	CD (0.05)	SEd	CD (0.05)
V	0.2	0.4	0.5	1.3
S	0.2	0.4	0.5	1.3
F	0.2	0.3	0.5	1
V x S	0.2	0.6	0.7	NS
S x F	0.2	0.6	0.8	NS
V x F	0.2	0.6	0.8	NS
F x S	0.2	0.5	0.7	NS
F x V	0.2	0.5	0.7	NS

V_1–SH4, V_2 - SUIN053, S_1 – 30 cm x 15 cm, S_2 – 45 cm x 15 cm, F_1 – 20:40:40 N, P_2O_5 & K_2O kg /ha, F_2 – 20:60:60 N, P_2O_5 & K_2O kg /ha, F_3 – 20:80:80 N, P_2O_5 & K_2O kg/ ha.

nutrients effectively in growth stages, which would have contributed for better plant growth, dry matter production and higher yield attributes. The results are in confirmation with the findings of Ulemale *et al*. (2002). Application of 20:80:80 kg N, P_2O_5, K_2O ha^{-1} eventually resulted in significantly higher seed.

Table 3. Effect of varieties, spacing and fertilizer levels on the seed yield (kg ha^{-1}) and seed yield based economics of Sunnhemp

Treatment		Seed yield (kg ha^{-1})				* Net return (Rs. ha^{-1})				* B:C ratio			
		F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
V_1	S_1	1120	1350	1420	1297	24795	35135	37260	32397	1.7	1.94	1.96	1.87
	S_2	970	1170	1210	1117	16970	25860	26540	23123	1.48	1.69	1.68	1.62
	Mean	1045	1260	1315	1207	20883	30498	31900	27760	1.59	1.82	1.82	1.74
V_2	S_1	895	1070	1120	1028	14360	21760	23000	19707	1.4	1.58	1.59	1.53
	S_2	770	925	960	885	7600	14005	14305	11970	1.21	1.38	1.37	1.32
	Mean	833	998	1040	957	10980	17883	18653	15838	1.31	1.48	1.48	1.42
		939	1129	1178		15931	24190	25276		1.45	1.65	1.65	
Mean	S_1	1008	1210	1270	1163	19578	28448	30130	26052	1.55	1.76	1.77	1.7
	S_2	870	1048	1085	1001	12285	19933	20423	17547	1.35	1.53	1.52	1.47

	Seed yield (kg ha^{-1})	
	SEd	CD (0.05)
V	21	51
S	21	51
F	19	41
V x S	29	NS
S x F	31	NS
V x F	31	NS
F x S	27	NS
F x V	27	NS

V_1–SH4, V_2 - SUIN053, S_1 – 30 cm x 15 cm, S_2 – 45 cm x 15 cm, F_1 – 20:40:40 N, P_2O_5 & K_2O kg /ha, F_2 – 20:60:60 N, P_2O_5 & K_2O kg /ha, F_3 – 20:80:80 N, P_2O_5 & K_2O kg/ ha. *- Data statistically not analysed.

However the yield obtained with a fertilizer dose 20:80:80 kg N, P_2O_5, K_2O ha^{-1} was at par with the yield of 20:60:60 kg N, P_2O_5, K_2O ha^{-1}. This finding is also in accordance with Deshmukh *et al.* (1997).

Economics

The higher gross return (Rs.76910 ha^{-1}), net return (Rs.38000 ha^{-1}) and BCR (1.96) was obtained from SH4 sown with a closer spacing of 30 x 15 cm and

NPK level of 20:80:80 kg N, P_2O_5, K_2O ha^{-1} when the crop is harvested for seed yield. However the BCR obtained with 20:80:80 kg N, P_2O_5, K_2O ha^{-1} for seed yield did not vary much with the level of 20:60:60 N, P_2O_5, K_2O ha^{-1}, application of 20:60:60 kg N, P_2O_5, K_2O ha^{-1} would be economical.

Table 4. Effect of varieties, spacing and fertilizer levels on Plant height (cm) and Fibre tenacity (g tex^{-1}) of Sunnhemp

Treatment		Plant height (cm)				* Fibre tenacity (g tex^{-1})			
		F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
V_1	S_1	195.2	210.3	211.6	205.7	14	17.9	18.2	16.7
	S_2	184.7	192.1	193.8	190.2	12.5	15.8	16.1	14.8
	Mean	190	201.2	202.7	198	13.3	16.9	17.2	15.8
V_2	S_1	202.2	214.7	216.1	211	15	19.1	19.5	17.9
	S_2	192.5	198.8	200.3	197.2	13	16.4	16.6	15.3
	Mean	197.4	206.8	208.2	204.1	14	17.8	18.1	16.6
		193.7	204	205.5		13.6	17.3	17.6	
Mean	S_1	198.7	212.5	213.9	208.4	14.5	18.5	18.9	17.3
	S_2	188.6	195.5	197.1	193.7	12.8	16.1	16.4	15.1

*- Data statistically not analysed.

Tenacity g tex^{-1}	Grade
< 15	Average
15-22	Fairly good

	Plant height	
	SEd	CD(0.05)
V	3.8	NS
S	3.8	9.4
F	3.5	7.4
V x S	5.4	NS
S x F	5.6	NS
V x F	5.6	NS
F x S	5	NS
F x V	5	NS

V_1–SH4, V_2 - SUIN053, S_1 – 30 cm x 15 cm, S_2 – 45 cm x 15 cm, F_1 – 20:40:40 N, P_2O_5 & K_2O kg /ha, F_2 – 20:60:60 N, P_2O_5 & K_2O kg /ha, F_3 – 20:80:80 N, P_2O_5 & K_2O kg/ ha.

B. Optimization of Plant Geometry and NPK levels for Fibre Yield Maximization in Sunnhemp.

Performance of varieties

Between the two varieties evaluated, the fibre yield (1055 kg ha^{-1}) and fibre tenacity (16.6 g tex^{-1}) were significantly higher with the variety SUIN 053. The results are in line with Saxena and Johansen (1990) who proposed the concept of functional ideotype by including morphological, phenological

Table 5. Effect of varieties, spacing and fertilizer levels on the fibre yield (kg ha^{-1}) and fibre yield based economics of Sunnhemp

Treatment		Fibre yield (kg ha^{-1})				* Net return (Rs. ha^{-1})				* B:C ratio			
		F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
V_1	S_1	815	870	900	862	14345	15925	16090	15453	1.42	1.44	1.42	1.43
	S_2	745	805	830	793	10145	12025	11890	11353	1.29	1.33	1.31	1.31
	Mean	780	838	865	828	12245	13975	13990	13403	1.35	1.39	1.37	1.37
V_2	S_1	925	1005	1055	995	20945	24025	25390	23453	1.61	1.66	1.67	1.65
	S_2	850	895	920	888	16445	17425	17290	17053	1.48	1.48	1.46	1.47
	Mean	888	950	988	942	18695	20725	21340	20253	1.54	1.57	1.56	1.56
		834	894	926		15470	17350	17665		1.45	1.48	1.47	
Mean	S_1	870	938	978	928	17645	19975	20740	19453	1.51	1.55	1.55	1.54
	S_2	798	850	875	841	13295	14725	14590	14203	1.38	1.41	1.38	1.39

	Fibre yield (kg ha^{-1})	
	SEd	**CD (0.05)**
V	17	42
S	17	42
F	15	33
V x S	24	NS
S x F	25	NS
V x F	25	NS
F x S	22	NS
F x V	22	NS

V_1–SH4, V_2 - SUIN053, S_1 – 30 cm x 15 cm, S_2 – 45 cm x 15 cm, F_1 – 20:40:40 N, P_2O_5 & K_2O kg /ha, F_2 – 20:60:60 N, P_2O_5 & K_2O kg /ha, F_3 – 20:80:80 N, P_2O_5 & K_2O kg/ ha. *- Data statistically not analysed.

and physiological and biochemical traits that could improve yield and quality in a specified target environment.

Influence of spacing

The results revealed that difference in plant height (cm) between the two plant geometry was significant (Table 4). Crop sown at a spacing of 30 cm x 15 cm produced taller plants as compared to wider spacing of 45 cm x15 cm. These findings are in line with the results by Shastri *et al.,* (2007) in sunnhemp. Between the two spacing studied, closer spacing of 30 cm x 15 cm registered significantly higher fibre yield (928 kg ha^{-1}) and higher fibre tenacity (17.3) as compared to 45 cm x 15 cm (840 kg ha^{-1}). These results are in corroboration with the findings of Ulemale and Shivankar (2003).

Influence of NPK levels

Among the different fertilizer levels, application of 20:80:80 N, P_2O_5, K_2O ha^{-1} resulted in taller plants and higher fibre tenacity (Table 4). Application of the major nutrients might have supplied the nutrients effectively in growth stages, which would have contributed for better plant growth and fibre quality. The results are in confirmation with the findings of Ulemale *et al*. (2002). Application of 20:80:80 kg N, P_2O_5, K_2O ha^{-1} eventually resulted in significantly higher fibre yield. However the yield obtained with a fertilizer dose 20:80:80 kg N, P_2O_5, K_2O ha^{-1} was at par with the yield of 20:60:60 kg N, P_2O_5, K_2O ha^{-1}. This finding is also in accordance with Deshmukh *et al.* (1997).

Economics

When the crop is harvested for fibre yield, the variety SUIN 053 sown with closer spacing of 30 x 15 cm and fertilizer level 20:80:80 kg N, P_2O_5, K_2O ha^{-1} obtained higher gross return (Rs.63300 ha^{-1}), net return (Rs.25390 ha^{-1}) and BCR 1.67. However the BCR obtained with 20:80:80 kg N, P_2O_5, K_2O ha^{-1} for fibre yield did not vary much with the level of 20:60:60 N, P_2O_5, K_2O ha^{-1}, application of 20:60:60 kg N, P_2O_5, K_2O ha^{-1} would be economical.

Conclusion

Based on the results from the above experiments, it is concluded that to obtain economical yield of seed, the variety SH 4 at a spacing of 30 x 15 cm with the application of NPK @ 20:60:60 kg N, P_2O_5, K_2O ha^{-1} may be recommended, while for obtaining economical yield of fibre, at the same spacing and fertilizer level, the variety SUIN 053 may be suggested.

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