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Assessment of Seed Yielding Potential of Sunnhemp (*Crotalaria juncea*) under Southern Plateau Zone of India

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ABSTRACT

Background: Sunnhemp is an important bast fibre crop suitable for diversified uses. Recently, its cultivation has started expanding considerably throughout the world particularly for its potential usage in sustainable farming and in reducing use of synthetic fertilizers from agricultural system. Seed production and fibre production are mutually exclusive in sunnhemp because of different photo-period requirements for these purposes and destructive fibre extraction process. The major limitation in sunnhemp popularization cultivation is availability of seed. In this context, present study was undertaken to identify proper sowing time and suitable cultivars, and find correlation of seed yield with weather parameters for Telangana state of India.

Methods: Three dates of sowing and six cultivars were tested in split-plot design over two years *i.e*., 2019-20 and 2020-21. Pooled data over two years were analyzed for important seed yield related traits.

Result: The analysis of variance revealed significant influences of sowing dates, cultivars and their interaction on majority of the traits. Among three sowing dates, 2nd week of September was the best suited for seed yield and related traits. The cultivar SUIN 037 recorded maximum seed yield followed by SUIN 053. Among different combinations of treatment, the cultivars SUIN 037 and SH 4 sown during 2nd week of September resulted in maximum and comparable seed yield. The correlation and regression studies showed that the weather parameters had significant influences on yield attributes of sunnhemp.

Key words: Cultivar, Fibre, Seed yield, Sowing date, Sunnhemp, Weather.

INTRODUCTION

Sunnhemp (*Crotalaria juncea* L.) is a member of fabaceae family and is the sole cultivated species in the genus *Crotalaria*. It is popular among Indian rural masses for its several beneficial uses. It is a native of India and is traditionally grown in tropical and subtropical countries like India, Pakistan, Brazil, Bangladesh *etc*. Recently, its cultivation has become possible in non-traditional parts of world like Americas. Its cultivation in India spans throughout the country with major areas in the states of Madhya Pradesh, Chhattisgarh, Odisha, Uttar Pradesh, Maharashtra, Tamil Nadu *etc*.

It has been an integral part of every Indian rural household for use as the source of natural fibres (Cordage, Twines, Tatpatti *etc*.). Green manuring capacity of this crop is well documented (Garrido *et al*., 2017; Irin *et al*., 2019). It is extensively used as cover crop on account of its rapid growth, extensive foliage and high biomass. It has the potential of improving soil physical, chemical and biological properties and hence, is an excellent agent for soil amendment. On account of its favorable green manuring features *viz*., ability to fix atmospheric nitrogen, high biomass, and amenability to decompose rapidly (Cho *et al*., 2015; Vanishree *et al*., 2019), it is placed in top among green manuring crops. It finds uses in industry as a source of paper-pulp, currency paper, cigarette paper, tissue paper *etc*. This crop has the potential to be used as a forage crop (Burke *et al*., 2011; Garzon *et al*., 2020) on account of higher biomass of its foliage (Cho *et al*., 2015) and availability of essential nutrients in its feedstock (Cantrell *et al*., 2010). It has the potential of reducing use of synthetic chemicals from agricultural system. Recently it has emerged as one of the most suitable candidates for biofuels (Cantrell *et al*., 2010; Sadhukhan and Sarkar, 2016; Xu *et al*., 2020).

Seed is the major limitation in sunnhemp and other bast fibre crops like jute (Bhandari *et al*., 2018) because of different photo-period requirements for seed crop and fibre crop. Further, unlike cereal crops, where the economic part is seed, in sunnhemp and other bast fibre crops, economic part is fibre extracted from its stem which is a destructive

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process. Thus, in sunnhemp, fibre and seeds are exclusive to each other. Sunnhemp requires short days for seed production therefore, pre-*rabi* season is considered the best time for its seed production in India. However, the cultivation of paddy during this period leaves little scope for farmers to produce sunnhemp seed. Kasirajan *et al.* (2021) demonstrated that differential season-related factors like cumulative heat units, relative temperature disparity *etc*. were the cue for two (fibre vs seed). Due to these reasons, seed production of sunnhemp in India is localized and largely unorganized thus impeding the availability of quality seeds to farmers to realize the yield potential of improved cultivars developed.

Very few studies have been conducted aiming at developing suitable agro-techniques for seed production. Some studies are available regarding different factors like topping, spacing, nutrition *etc*. affecting seed yield in sunnhemp (More *et al*., 2018; Tripathi *et al*., 2013) but the studies regarding sowing date, cultivar effects and crop-weather relationship are lacking. Seeing the surging demand of sunnhemp, location-specific technique needs to be developed for seed production in sunnhemp. In this context, present investigation was carried out at Telangana state (representing southern plateau zone) of India to study the influence of sowing dates and cultivars on seed yield in sunnhemp, and to study crop-weather interaction in seed crop of sunnhemp.

MATERIALS AND METHODS

The present investigation was carried out at Agricultural Research Station, Kunaram in the district of Peddapally in the northern part of Telangana state, India during two years (2019-20 and 2020-21). Kunaram is located at 18.52°N latitude, 79.49°E latitude and at an altitude of 231 m above mean sea level. The soil of the site was red loamy soil in texture and saline in reaction. The experiment was laid out in split-plot design with three replications. The main factors included date of sowing and sub-factors included cultivars. Three sowing dates (2nd week of September, 3rd week of September and 2nd week of October) and six released cultivars of sunnhemp (JRJ 610, SUIN 037, SUIN 053, SH4, K 12 Yellow and Type 6) received from ICAR-CRIJAF, Barrackpore were tested for seed yield and related partameters. Each cultivar was sown in plot of 6.0 × 4.5 m size. An inter-row spacing of 45 cm and inter-plant distance of 20 cm was maintained. All the recommended package of practices was followed to get a healthy crop.

Data on different seed yield parameters (plant height at harvest, number of primary branches per plant number of secondary branches per plant, pod weight per plant, number of seeds per pod, test weight and seed yield) were recorded. Pooled data over two years (2019-20 and 2020-21) were analyzed.

The model followed for data analysis was:

$$Y_{ijk} = \mu + r_i + m_j + m_{ij} + s_k + (ms)_{jk} + e_{ijk}$$

Where

Y_{ijk} = Observation of ith replication, j^{th} main plot and k^{th} subplot.
μ = Overall mean.
r_i = Effect of ith replication.
m_j = Effect of main plot.
m_{ij} = Main plot error.
s_k = Effect of subplot.
ms_{jk} = Interaction effect.
e_{ijk} = Error component for subplots and interaction.

The treatment-wise data on seed yield and related traits were correlated with weather parameters prevailing during the crop period using T-test. The meteorological data were averaged for two years. The significant relationship was further regressed using the stepwise regression to arrive at valid regression equation by using SPSS (Statistical Package for the Social Sciences) software.

RESULTS AND DISCUSSION

Yield and yield attributes

Analysis of variance

The analysis of variance (Table 1) revealed significant influence of sowing dates for plant height, number of primary branches/plants, number of secondary branches/plants, pod weight per plant and seed yield. Cultivars had considerable influences on the expression of all the traits under study. Similarly, the interaction of sowing dates and cultivars had also significant effects on all the traits with the exception of the trait number of primary branches per plant.

The ANOVA table (Table 1) revealed that the traits number of seeds per pod and test weight remained unaffected by sowing dates but affected by cultivars. Non-significant effect of sowing date, cultivar and their interaction on seed weight has been reported in sunflower (Demir, 2019).

Influence of sowing date

Data based on pooled analysis revealed that 2nd week of September was the best suited with respect to majority of the traits followed by that of 3rd week of September (Table 2). The crop sown during 2nd week of October experienced extreme reduction in measurement for most growth and yield parameters. The earlier studies also reported significant effect of sowing dates on seed yield in different crops (Jiotode *et al*., 2016).

Distinctly superior plant height (167.8 cm) was noted in the crop sown during 2nd week of September. Further delay in sowing of crop during 3rd week of September and 2nd week of October resulted in significant reduction in height (163.2 cm and 116.3 cm, respectively). Similarly, maximum number of primary branches per plant (6.6) was noted in the crop sown during 2nd week of September followed by that sown during 3rd week of September (6.1) with only numerical differences between them. Among three sowing dates, 2nd week of September appeared best with respect to number of secondary branches per plant (22.8). The crop sown

Table 1: Analysis of variance for growth and seed yield parameters in sunnhemp.

Source of variation /Trait	PH (cm)	NPB/Pl	NSB/Pl	Pod wt/ Pl	No of seeds/ pod	Test wt	Seed yield
Replication	42.2	0.2	316.2	18.8	0.3	20.2	4.9
Date of sowing	11288.4*	28.9*	14997.1*	986.6*	2.1	12.7	1585.9*
Error (A)	40.5	0.4	112.5	7.1	0.4	3.1	5.1
Cultivar	1582.8*	0.6*	90.2	18.8*	0.9*	4.9*	19.4*
Date of sowing × Cultivar	2513.9*	0.4	157.7*	17.3*	1.6*	7.5*	22.2*
Error (B)	398.0	0.2	44.3	2.8	0.3	1.4	2.4

Table 2: Influence of date of sowing on different growth and seed yield parameters of sunnhemp.

Traetment/ Trait	PH (cm)	NPB/ Pl	NSB/ Pl	Pod wt/ Pl (g)	No of seeds/ pod	Test weight (g)	Seed yield (Q/ha)
Date of sowing							
Sept 2nd Week	167.8	6.6	22.8	35.7	7.9	37.4	33.6
Sept 3rd Week	163.2	6.1	17.0	26.5	8.4	36.7	25.2
Oct 2nd Week	116.3	4.3	11.1	22.0	8.0	38.8	14.5
SEm±	0.8	0.2	0.2	0.6	0.2	0.6	0.5
CD (p=0.05)	2.94	0.6	0.7	2.5	NS	NS	2.1
Cultivars							
Prankur (JRJ610)	149.1	5.8	16.7	27.1	8.1	38.2	23.8
SUIN 037(Ankur)	144.0	5.8	17.4	27.8	7.6	37.1	26.0
SUN 053 (Swastika)	151.2	5.5	16.5	30.0	8.2	38.0	24.0
SH-4	152.0	5.5	17.4	27.3	8.4	37.2	23.9
K12 Yellow	161.8	5.2	15.7	29.7	8.5	38.9	21.5
Type 6	154.8	5.4	16.7	30.2	8.4	38.0	22.9
SEm±	1.2	0.2	0.3	0.6	0.2	0.6	0.5
CD (p=0.05)	3.51	0.4	0.9	1.6	0.6	1.1	1.5

PH: Plant height, NPB/Pl: Number of primary branches per plant, NSB/Pl: Number of secondary branches per plant, Pod wt/Pl: Pod weight per plant.

during 2nd week of September recorded maximum pod weight per plant (35.7 g) followed by that sown during 3rd week of September (26.5 g) with considerable differences between them. Similarly, maximum seed yield (33.6 Q/ha) was achieved when the crop was sown during 2nd week of Sept. It was followed by that of crop sown during 3rd week of Sept (25.2 g). Other traits like test weight and number of seeds per pod remained unaffected by sowing date. Similar observations were made in soybean (Borowska and Prusinski, 2021) and in jute (Patra *et al*., 2017) where test weight was not affected by dates of sowing. Contrary findings with respect to seed weight in jute were reported by Alam and Haque (2019).

Maximum seed yield obtained by sowing of crop during 2nd week of September may be ascribed to optimum growth and proper development of branches which in turn, may be favoured by environmental conditions. Dukre *et al*. (2000) reported that 21st September was the best sowing time for seed yield in sunnhemp under Maharashtra condition. Reduced seed yield in delayed sowing in present study may be ascribed to photoperiod sensitive nature of sunnhemp resulting in induction of flowering with the onset of shorter days irrespective of crop age leading to lack of proper development of plant and its branches which bears flowers. Previous study in jute corroborates this finding (Kumar *et al*., 2013).

Influence of cultivars

The cultivars had significant effects on different growth and seed yield parameters of sunnhemp (Table 2). The cultivar K 12 yellow recorded significantly more height (161.8 cm) than other cultivars. In contrast, all cultivars except K 12 yellow recorded similar number of primary branches (5.2 to 5.4) and secondary branches (16.5 to 17.4) per plant. The cultivar K 12 yellow had least number of primary branches (5.2) and secondary branches (15.7). Among the tested cultivars, Type 6, SUIN 053 and K 12 yellow were superior in terms of pod weight per plant and recorded equivalent pod weight of 30.2 g, 30.0 g and 29.7 g, respectively. All the cultivars were reported to have equivalent number of seeds per pod except the cultivar SUIN 037 which recorded least number of seeds per pod (7.6). Similarly, four out of six cultivars tested had similar test weight ranging from 38.0 g to 38.9 g, the maximum recorded by the cultivar K 12 yellow. The cultivars SUIN 037 and SH 4 recorded least test weight (37.1 g and 37.2 g, respectively). The cultivar SUIN 037 recorded maximum seed yield (26.0 Q/ha) and was distinctly superior to all other cultivars. The 2nd best cultivar was SUIN 053 with seed yield of 24.0 Q/ha followed by SH 4.

Table 3: Interaction effect of sowing dates and varieties on seed yield parameters.

Treatment/Traits	PH (cm)	NPB/Pl	NSB/ Pl	Pod wt (g)/ Pl	No of seeds/ pod	Test weight (g)	Seed yield (Q/ha)
D1V1	164.9	6.5	18.4	33.7	7.8	38.5	20.6
D1V2	165.2	7.0	24.9	37.5	7.8	38.7	25.6
D1V3	171.5	6.4	24.3	34.7	8.1	37.0	20.6
D1V4	169.6	6.4	23.8	36.7	7.9	35.3	23.1
D1V5	175.4	6.5	23.4	36.2	7.9	37.4	22.9
D1V6	156.7	6.7	22.6	39.8	7.7	38.8	22.2
D2V1	169.2	6.1	19.6	25.6	8.6	35.5	15.2
D2V2	154.0	5.9	16.7	26.1	7.5	37.0	15.1
D2V3	168.6	5.9	14.2	29.9	8.7	37.5	16.4
D2V4	160.9	6.3	17.6	24.4	8.7	36.9	12.7
D2V5	179.6	5.3	14.5	32.1	7.8	38.6	15.8
D2V6	163.9	5.6	16.9	29.9	9.9	38.8	17.1
D3V1	113.2	5.0	12.0	22.0	8.1	40.7	9.4
D3V2	112.9	4.5	10.5	19.8	7.6	35.4	9.6
D3V3	113.5	4.1	10.9	25.4	7.7	39.7	11.9
D3V4	125.6	3.8	10.9	20.9	8.5	39.3	7.6
D3V5	130.4	3.6	9.2	20.9	9.7	39.2	8.2
D3V6	143.7	3.8	10.5	21.0	7.7	39.4	7.9
SEm ±	2.1	0.3	0.5	0.96	0.3	0.7	0.9
CD (P 0.05)	6.1	NS	1.5	2.8	1.0	2.0	2.6

D1: 2nd week of September, D2: 3rd week of September, D3: 2nd week of October

V1: JRJ 610, V2: SUIN 037, V3: SUIN 053, V4: SH 4, V5: K 12 Yellow, V6: Type 6.

The cultivar K 12 yellow recorded the least seed yield (21.5 Q/ha). Differential seed yielding ability of different genotypes/ cultivars of sunnhemp has been demonstrated earlier (Kasirajan *et al*., 2021).

The interaction table (Table 3) revealed significant interaction between sowing dates and cultivars for all the traits except number of primary branches per plant. Maximum plant height was noted by the cultivar K 12 yellow sown during 3rd week of September (179.6 cm) followed by the same cultivar (K 12 yellow) sown during 2nd week of September (175.4 cm) with no significant differences between them. The next best treatment combination was cultivar SUIN 053 sown during 2nd week of September. Significantly a greater number of secondary branches per plant was noted by the cultivar SUIN 037 sown during 2nd week of September (24.9). Comparable number of secondary branches per plant was noted by other cultivars *viz*., SUIN 053 (24.3), SH 4 (23.8), and K 12 yellow (23.4) all sown during 2nd week of September. The maximum pod weight per plant was noted by the genotype Type 6 (39.8 g) followed by the cultivar SUIN 037(37.5 g) both sown during 2nd week of September with no statistical differences between them. Two treatment combinations *viz*., Type 6 sown during 3rd week of September and K 12 yellow sown during 2nd week of October recorded maximum number of seeds per pod (9.9 and 9.7, respectively) with minor differences between them. With respect to test weight, eight treatment combinations were found equally superior with maximum test weight noted the cultivar JRJ 610 (40.7 g) followed by SUIN 053 (39.7 g), Type 6 (39.4 g) and SH 4 (39.3 g), all sown during 2nd week of October. Seed yield per hectare ranged from 7.6 Q to 25.6 Q. The maximum seed yield was achieved when the cultivar SUIN 037 (25.6 Q) and SH 4 (23.1 Q) sown during 2nd week of September and were comparable to each other. The next best treatment combinations were variety K 12 yellow and Type 6 sown during 2nd week of September (22.9 and 22.2 Q/ha, respectively). Significant effects of cultivars and sowing dates on growth and stalk yield in sunnhemp was reported by Cook *et al*. (1998). Similar reports are available for seed yield and related parameters in jute (Kumar *et al*., 2013).

Correlation and regression studies between weather parameters and seed yield attributes of sunnhemp

The correlation studies between different weather parameters (Tmax: mean maximum temperature, Tmin: Mean minimum temperature, RH-I: Relative Humidity during morning, RH-II: Relative humidity during afternoon and RF: total rainfall) revealed that the all the weather parameters had significantly positive correlation with pod weight per plant (Table 4). This is in agreement with earlier reports in linseed (Jiotode *et al*., 2016).

Present study revealed that the trait number of seeds per pod was not significantly correlated with any weather parameter. Similarly, test weight was also not affected by any weather parameter except relative humidity at afternoon. Seed yield was positively and significantly correlated with all-weather parameters except bright sunshine hours. The significantly negative correlation of seed yield with bright sunshine hours indicated that longer

Table 4: Correlation between weather parameters and seed yield attributes of sunnhemp.

Weather parameters	Pod weight/plant (g)	No. of seeds/pod	Test weight (g)	Seed yield (q/ha)
Tmax	0.787**	-0.132	-0.309	0.773**
Tmin	0.559*	-0.297	-0.295	0.518*
RH I	0.563*	-0.372	-0.396	0.726**
RH II	0.644**	-0.267	-0.522*	0.829**
BSSH	-0.595**	0.441	0.309	-0.640**
RF	0.852**	-0.091	-0.427	0.906**

Table 5: Step wise regression equation between weather parameters and seed yield attributes of sunnhemp.

Response factor (Y)	Regression equation	R^2	F Change
Pod weight plant^{-1}	Y=167.36-0.45Tmax+0.008Tmin-0.039RHI-0.83RHII-12.24BSSH+0.04RF	0.83	9.12
No of seeds pod^{-1}	Y=72.48-0.75Tmax-0.18Tmin-0.45RHI-0.013RHII+0.78BSSH+0.004RF	0.47	1.67
Test wt	Y=37.37-0.68Tmax-0.066Tmin+0.53RHI-0.30RHII-1.18BSSH+0.003RF	0.32	0.86
Seed yield	Y=91.44-0.20Tmax-0.25Tmin-0.48RHI+0.098RHII-6.47BSSH+0.032RF	0.83	9.50

**: Significant at the 0.01; *: Significant at the 0.05.

Tmax: Mean maximum temperature, Tmin: Mean minimum temperature, RH-I: Relative humidity during morning, RH-II: Relative humidity during afternoon, BSSH: Bright sunshine hours, RF: Total rainfall.

days reduced seed yield and thereby late-sown crop recorded lower seed yield. Similar findings were reported in red fire spike (Rezazadeh *et al*., 2018). The mean bright sunshine hours (BSSH) showed positively correlated with seeds pod^{-1} and test weight and significantly negatively correlated with no. of pods plant $^{-1}$, seed yield and biomass yield. Similar result was reported in potato cultivars by Yogesh *et al*. (2019). Significant positive correlation of seed yield with total rainfall during the crop period has been reported earlier in soybean (Sobko *et al*., 2020).

Step wise regression equations between seed yield and related traits (pod weight per plant, no. of seeds per pod, test weight and seed yield) and weather parameters revealed that the studied weather parameters accounted for 32%, 47%, 83% and 83% variation in test weight, number of seeds per pod, pod weight per plant and seed yield, respectively (Table 5). Earlier reports (Raju and Narayanan, 2017) also indicated the impact of weather parameters such as minimum temperature, morning and evening relative humidity on grain yield in aerobic rice.

CONCLUSION

Sowing dates, cultivars and their interaction had considerable impact on growth and seed yield parameters. The present study established that among tested dates of sowing, 2nd week of September was best suited for important growth and seed yield parameters under Telangana condition and among the varieties, the variety SUIN 037 had the maximum seed yield followed by SUIN 053. Among different treatment combinations, sowing of variety SUIN 037 and SH 4 during 2nd week of September resulted in maximum seed yield.

Conflict of interest

Authors have declared that no competing interests exist.

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