

Original Research Article

Growing Green: Unravelling Trait Associations in Sunnhemp (*Crotalaria juncea* L.) for higher biomass.

ABSTRACT

Sunnhemp (*Crotalaria juncea* L.) is a leguminous crop native to India, cultivated for its industrial value and soft fibre. Its high biomass and nutrient content make it suitable for fodder and green manure. As a legume, it thrives on poor or reclaimed soil, serving as a soil builder and nematode deterrent. In this study, the investigation was carried out with the objective of elucidating the associations among traits and its contribution towards high biomass in sunnhemp. Genotypic correlation analysis revealed significant associations between biomass and traits such as number of primary branches (0.631), dry matter yield (0.543), leaf length (0.540) and leaf width (0.470). Phenotypic correlation analysis demonstrated that biomass showed positive correlation with number of primary branches (0.604), dry matter yield (0.540), leaf length (0.539) and plant height (0.456). In addition to this, path analysis revealed the direct and indirect effect of traits towards biomass yield. The trait dry matter yield (1.421) exhibited the highest positive direct effect towards biomass yield. These findings suggest that selecting of plants for plant height, leaf length, leaf width, dry matter yield and primary branch count can enhance biomass in sunnhemp breeding programs, which will increase its value further as green manure crop.

Keywords: Sunnhemp, high biomass, correlation, path analysis, selection criteria

1. INTRODUCTION

Sunnhemp (*Crotalaria juncea* L.) belonging to Fabaceae family is commercially cultivated for its industrial values and soft fibre. Because of its high biomass and nutrient content, it is also being cultivated as fodder and green manure crop (Mondin et al. 2007). The crop being a legume is having advantage of growing in fields with less resources or freshly reclaimed soil where its major role would be soil builder or renovator. The crop once a major commercial crop was replaced by cultivation of other high value crops. At present, the use of chemical fertilizers has become dominant among developed as well as developing countries, leading to continuous agroecosystem damage. This has become the major concern for the current day and scientists of early days of green revolution (Agarwal 1959 ; Kanwar and Singh 1959 ; Panse et al. 1965 ; Tandon et al. 1959). Sunnhemp can play a major role in solving these problems as green manure crop, which maintains the soil health and agroecosystem (Bhardwaj and Datt 1995 ; Gupta and Tripathi 1999). After huge hike in fertilizer price, farmers realized the value of green manure crop and returned back to the cultivation of sunnhemp as nutrient supplement. Sunnhemp cultivation not only increases the soil health but also helps in increasing the water holding capacity of the soil by addition of large amount of organic matter.

High magnitude of variability in a population provides the opportunity for selection to evolve a variety having desirable characters (Desai Tarjani et al. 2020b ; Maruthi et al. 2024). Information on association of characters, direct and indirect effects contributed by each character towards biomass will be an added advantage in aiding the selection process. Correlation and path analysis establish the extent of association between biomass and its components and also bring out relative importance of their direct and indirect effects, thus giving an obvious understanding of their association with high biomass. Ultimately, this kind of analysis could help the breeder to design his selection strategies to improve biomass content. In the context, the investigation was carried out with the objective of elucidating the associations among traits and its contribution towards high biomass in sunnhemp.

2. MATERIALS AND METHODS

The current investigation was carried out at the Department of Genetics and Plant Breeding, Tamil Nadu Agricultural University, Coimbatore (11°N latitude and 77°E longitude) during *Kharif* 2019–2020. The experiment was laid out in a Randomized Block Design (RBD) with three replications. The experimental material comprised of twenty germplasm accessions collected from different parts of Tamil Nadu and also from CRIJAF (ICAR-Central Research Institute for Jute and Allied Fibres, Barrackpore). Each accession was raised in 4 m x 2 m sized plot with 60 cm spacing between rows. All necessary precautions were taken to maintain uniform plant population in each treatment per replication. All the recommended package of practices was followed along with necessary prophylactic plant protection measures to raise a good crop. Observations were recorded for traits such as plant height (cm), leaf length (cm), leaf width (cm), number of leaves per plant, stem girth (cm), days to first flowering, days to 50% flowering, number of primary branches, number of secondary branches, root length, dry matter yield (kg/plot), moisture content and biomass yield (kg/plot) and the data was subjected to statistical analysis. Association among biomass and its contributing traits were elucidated through correlation analysis suggested by Johnson et al. (1955), which provides us the direction of association. The cause and effect of different traits towards the biomass was interrupted through path analysis given by Wright (1921) and illustrated by Dewey and Lu (1959).

3. RESULTS AND DISCUSSION

3.1 Correlation analysis

3.1.1 Genotypic correlation

The results of genotypic correlation analysis were presented in table 1. Biomass yield per plant demonstrated positive and highly significant association with number of primary branches (0.631), whereas it exhibited positive and significant association with dry matter yield (0.543), leaf length (0.540), leaf width (0.470). Plant height registered positive and highly significant association with stem girth (0.697), positive and significant association with leaf length (0.559) and leaf width (0.551). Leaf length showed positive and highly significant association with leaf width (0.758), positive and significant association with plant height (0.559), stem girth (0.509) and dry matter yield (0.480).

Table 1. Genotypic correlation among biomass contributing traits

Traits	PH	LL	LW	NLP	SG	DF	DFF	NPB	NSB	RL	DMY	MC	BMY
PH	1.000	0.559*	0.551*	0.401	0.697**	0.085	0.147	0.307	0.257	0.215	0.411	-0.135	0.455
LL		1.000	0.758**	-0.150	0.509*	-0.212	-0.076	0.450	0.311	0.251	0.480*	-0.150	0.540*
LW			1.000	-0.195	0.435	0.040	0.213	0.442	0.230	-0.106	0.446	-0.138	0.470*
NLP				1.000	0.374	0.419	0.172	0.094	0.255	0.252	0.043	0.153	0.278
SG					1.000	0.034	0.049	0.296	0.481*	0.050	0.249	-0.111	0.272
DF						1.000	0.743**	0.120	0.162	-0.092	0.111	0.008	0.167
DFF							1.000	0.221	0.301	-0.102	0.355	-0.184	0.288
NPB								1.000	0.388	-0.104	0.525*	-0.112	0.631**
NSB									1.000	0.175	0.251	-0.017	0.369
RL										1.000	-0.119	0.299	0.242
DMY											1.000	-0.741**	0.543*
MC												1.000	0.154
BMY													1.000

*, ** Significant at 5 and 1 per cent probability level, respectively.

PH - Plant height
 LL - Leaf length
 LW - Leaf width
 NLP - No. of leaves per plant

SG - Stem girth
 DF - Days to first flowering
 DFF - Days to 50 % flowering
 NPB - No. of primary branches

NSB - No. of secondary branches
 RL - Root length
 DMY - Dry matter yield
 MC - Moisture content
 BMY - Biomass yield

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Leaf width had positive and highly significant association with leaf length (0.758), positive and significant association with plant height (0.551). Stem girth registered positive and highly significant association with plant height (0.697), whereas positive and significant association with leaf length (0.509) and number of secondary branches (0.481). Days to first flowering demonstrated positive and highly significant association with days to 50 % flowering (0.743). Days to 50 % flowering demonstrated positive and highly significant association with days to first flowering (0.743). Number of primary branches demonstrated positive and significant association with dry matter yield (0.525). Number of secondary branches demonstrated positive and significant association with stem girth (0.481). Dry matter yield demonstrated positive and significant association with number of primary branches (0.525) and leaf length (0.480). Dry matter yield exhibited negative and highly significant association with moisture content (-0.741). Moisture content registered negative and highly significant association with dry matter yield (-0.741). Similar results were reported by Desai Tarjani et al. (2020a).

3.1.2 Phenotypic correlation

The results of phenotypic correlation analysis were presented in table 2. Biomass yield per plant demonstrated positive and highly significant association with number of primary branches (0.604), It had positive and significant association with dry matter yield (0.540), leaf length (0.539) and plant height (0.456). Plant height registered positive and highly significant association with stem girth (0.686), it exhibited positive and significant association with leaf length (0.556) and leaf width (0.516). Leaf length exhibited positive and highly significant association with leaf width (0.748), positive and significant association with plant height (0.556), stem girth (0.523) and dry matter yield (0.493). Leaf width exhibited positive and highly significant association with leaf length (0.748), positive and significant association with plant height (0.516), stem girth (0.473), dry matter yield (0.469) and number of primary branches (0.465). Stem girth registered positive and highly significant association with plant height (0.686). Positive and significant association with leaf length (0.523), number of secondary branches (0.479) and leaf width (0.473). Days to first flowering demonstrated positive and highly significant association with days to 50 % flowering (0.743). Days to 50 % flowering demonstrated positive and highly significant association with days to first flowering (0.743). Number of primary branches demonstrated positive and significant association with dry matter yield (0.524) and leaf width (0.465). Number of secondary branches registered positive and significant association with stem girth (0.479). Dry matter yield demonstrated positive and significant association with number of primary branches (0.524), leaf length (0.493) and leaf width (0.469). Dry matter yield exhibited negative and highly significant association with moisture content (-0.748). Moisture content registered negative and highly significant association with dry matter yield (-0.748). Similar results were reported by Desai Tarjani et al. (2020a).

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Table 2. Phenotypic correlation among biomass contributing traits

Traits	PH	LL	LW	NLP	SG	DF	DFF	NPB	NSB	RL	DMY	MC	BMY
PH	1.000	0.556*	0.516*	0.402	0.686**	0.085	0.146	0.295	0.257	0.201	0.409	-0.137	0.456*
LL		1.000	0.748**	-0.145	0.523*	-0.210	-0.075	0.451	0.314	0.287	0.493*	-0.171	0.539*
LW			1.000	-0.172	0.473*	0.037	0.197	0.465*	0.231	0.086	0.469*	-0.192	0.445
NLP				1.000	0.371	0.418	0.172	0.093	0.255	0.234	0.045	0.147	0.278
SG					1.000	0.034	0.048	0.317	0.479*	0.138	0.274	-0.143	0.272
DF						1.000	0.743**	0.114	0.162	-0.082	0.109	0.008	0.167
DFF							1.000	0.210	0.300	-0.091	0.350	-0.181	0.288
NPB								1.000	0.391	0.003	0.524*	-0.141	0.604**
NSB									1.000	0.178	0.255	-0.026	0.369
RL										1.000	-0.031	0.186	0.229
DMY											1.000	-0.748**	0.540*
MC												1.000	0.147
BMY													1.000

*, ** Significant at 5 and 1 per cent probability level, respectively.

PH - Plant height
 LL - Leaf length
 LW - Leaf width
 NLP - No. of leaves per plant

SG - Stem girth
 DF - Days to first flowering
 DFF - Days to 50 % flowering
 NPB - No. of primary branches

NSB - No. of secondary branches
 RL - Root length
 DMY - Dry matter yield
 MC - Moisture content
 BMY - Biomass yield

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Genotypic and phenotypic correlation coefficients revealed that the characters such as plant height, leaf length, leaf width, number of primary branches and dry matter yield registered significant positive correlation with biomass yield of the plant. As our trait of interest is biomass, genotypes with high vegetative growth in short term with high nutrient content is preferable. High plant height, high leaf length, leaf width, stem girth and dry matter yield could contribute unquestionably to high biomass, which could result in crop with high biomass. Therefore, plant height, leaf length, leaf width, stem girth, number of primary branches and dry matter yield would be important selection criteria for improvement in biomass of the crop.

3.2 Path analysis

The estimates of path coefficient analysis are furnished for biomass and biomass component characters in table 3. The results of path co-efficient analysis disclosed that dry matter yield (1.421) exhibited the highest positive direct effect followed by moisture content (1.207), leaf length (0.051), root length (0.038) and days to 50% flowering (0.035). Similar results were reported by Desai Tarjani et al. (2020a).

Plant height registered highest positive indirect effect with biomass through dry matter yield (0.584) followed by stem girth (0.046). Whereas, plant height registered negative indirect effect with biomass through moisture content (-0.163) followed by leaf width (-0.030). Leaf length exhibited highest positive indirect effect through dry matter yield (0.683) followed by stem girth (0.033). Leaf length exhibited negative indirect effect through moisture content (-0.180) followed by leaf width (-0.041). Leaf width displayed positive indirect contribution towards biomass through dry matter yield (0.634) followed by leaf length (0.039). In addition to that, leaf width displayed negative indirect effect through moisture content (-0.167) followed by plant height (-0.014). Number of leaves exhibited positive indirect effect towards biomass through moisture content (0.185) followed by dry matter yield (0.060). Number of leaves displayed negative indirect effect towards biomass through plant height (-0.010) followed by leaf length (-0.008). Stem girth exhibited positive indirect effect towards biomass through dry matter yield (0.354) followed by leaf length (0.026). In addition to that, stem girth registered negative indirect effect through moisture content (-0.134) followed by leaf width (-0.024). Days to first flowering displayed positive indirect contribution with regard to biomass through dry matter yield (0.158) followed by days to 50 % flowering (0.026). Along with these, days to first flowering exhibited negative indirect effect through leaf length (-0.011) followed by root length (-0.004). Days to 50 % flowering exhibited positive indirect effect with regard to biomass through dry matter yield (0.504) followed by number of primary branches (0.003). Days to 50 % flowering registered negative indirect effect towards biomass via moisture content (-0.222) followed by leaf width (-0.012). Number of primary branches showed positive indirect contribution towards biomass by means of dry matter yield (0.746) followed by leaf length (0.023). In addition, it exhibited negative indirect contribution towards biomass via moisture content (-0.136) followed by leaf width (-0.024). Number of secondary branches registered positive indirect effect towards biomass through dry matter yield (0.356) followed by stem girth (0.031). Whereas, number of secondary branches registered

negative indirect effect towards biomass by means of moisture content (-0.021) followed by leaf width (-0.013).

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Table 3. Genotypic path analysis showing direct (diagonal) and indirect effects of traits on biomass yield

Traits	PH	LL	LW	NLP	SG	DF	DFF	NPB	NSB	RL	DMY	MC	BMY
PH	-0.024	0.029	-0.030	0.003	0.046	-0.001	0.005	0.004	-0.005	0.008	0.584	-0.163	0.455
LL	-0.014	0.051	-0.041	-0.001	0.033	0.002	-0.003	0.006	-0.006	0.010	0.683	-0.180	0.540*
LW	-0.014	0.039	-0.055	-0.001	0.028	0.000	0.007	0.006	-0.004	-0.004	0.634	-0.167	0.470*
NLP	-0.010	-0.008	0.011	0.007	0.024	-0.005	0.006	0.001	-0.005	0.010	0.060	0.185	0.278
SG	-0.017	0.026	-0.024	0.003	0.065	0.000	0.002	0.004	-0.008	0.002	0.354	-0.134	0.272
DF	-0.002	-0.011	-0.002	0.003	0.002	-0.011	0.026	0.002	-0.003	-0.004	0.158	0.009	0.167
DFF	-0.004	-0.004	-0.012	0.001	0.003	-0.008	0.035	0.003	-0.005	-0.004	0.504	-0.222	0.288
NPB	-0.008	0.023	-0.024	0.001	0.019	-0.001	0.008	0.014	-0.007	-0.004	0.746	-0.136	0.631**
NSB	-0.006	0.016	-0.013	0.002	0.031	-0.002	0.011	0.005	-0.018	0.007	0.356	-0.021	0.369
RL	-0.005	0.013	0.006	0.002	0.003	0.001	-0.004	-0.001	-0.003	0.038	-0.169	0.361	0.242
DMY	-0.010	0.025	-0.024	0.000	0.016	-0.001	0.012	0.007	-0.004	-0.005	1.421	-0.895	0.543*
MC	0.003	-0.008	0.008	0.001	-0.007	0.000	-0.006	-0.002	0.000	0.012	-1.054	1.207	0.154

*, ** Significant at 5 and 1 per cent probability level, respectively. Residue = 0.1111

PH - Plant height
 LL - Leaf length
 LW - Leaf width
 NLP - No. of leaves per plant

SG - Stem girth
 DF - Days to first flowering
 DFF - Days to 50 % flowering
 NPB - No. of primary branches

NSB - No. of secondary branches
 RL - Root length
 DMY - Dry matter yield
 MC - Moisture content
 BMY - Biomass yield

Root length registered positive indirect contribution towards biomass through moisture content (0.361) followed by leaf length (0.013). In addition to that root length exhibited negative indirect contribution towards biomass by means of dry matter yield (-0.169) followed by plant height (-0.005). Dry matter yield displayed positive indirect contribution with regard to biomass through leaf length (0.025) followed by stem girth (0.016). Along with these, dry matter yield exhibited negative indirect effect through moisture content (-0.895) followed by leaf width (-0.024). Moisture content exhibited positive indirect effect with regard to biomass through root length (0.012) followed by leaf width (0.008). Moisture content registered negative indirect effect towards biomass via dry matter yield (-1.054) followed by leaf length (-0.008).

The outcomes of path co-efficient analysis disclosed that dry matter yield exhibited the highest positive direct effect followed by moisture content, stem girth, leaf length, root length, days to 50 % flowering, number of primary branches and number of leaves per plant towards the biomass. On the other hand, characters such as leaf width, plant height, number of secondary branches and days to first flowering exhibited negative direct effect towards the biomass yield of the crop. While indirect contribution is significantly higher, the characters bequeathing indirect contribution could also be included in selection strategy for the effective crop improvement programme. In the light of results obtained in present study, the highest indirect effect on biomass was exhibited by number of primary branches followed by leaf length through dry matter yield.

Selection of the genotypes should be done very prudently keeping in view higher dry matter yield plant per plant along with a greater number of primary branches plant per plant, plants with higher plant height, higher leaf length, higher leaf width, greater number of leaves per plant and higher stem girth to improve biomass yield per plant in sunnhemp. The lines may be used in further hybridization program and these crosses may yield more transgressive segregants for these traits for biomass improvement.

4. CONCLUSION

Association between biomass and its contributing characters revealed that traits such as, plant height, leaf length, leaf width, stem girth, number of primary branches and dry matter yield contributed for the high biomass yield per plant. Use of these traits associated with high biomass in selection will help to bring improvement in the biomass of the crop. The results of path co-efficient analysis showed that selection of characters such as dry matter yield, moisture content, number of leaves per plant, days to 50 % flowering, number of secondary branches, leaf length, stem girth and root length had high direct effect on biomass yield per plant. These results inferred that plant height, leaf length, leaf width, stem grith, number of primary branches and dry matter yield could be used in selection for biomass improvement of sunnhemp crop.

REFERENCES

- Agarwal J (1959) Response of wheat yields to different green manure crop. Allahabad Farming 30 (2):87-90
- Bhardwaj K K R, Datt N (1995) Effects of legume green-manuring on nitrogen mineralization and some microbiological properties in an acid rice soil. Biology and Fertility of Soils 19 (1):19-21
- Desai Tarjani B, Bala M, Patel R (2020a) Correlation studies for green manuring traits in sunnhemp (*Crotalaria juncea* (L.)). The Pharma Innovation Journal 9 (8):180-183
- Desai Tarjani B, Bala M, Patel R (2020b) Genetic variability study for green biomass attributing traits in Sunnhemp [*Crotalaria juncea* (L.)]. Advances in Bioresearch 11 (3):104-107
- Dewey D R, Lu K H (1959) A Correlation and path-coefficient analysis of components of crested wheatgrass seed production. Agronomy Journal 51 (9):515-518
- Gupta B N, Tripathi S N (1999) Studies on the influence of growing sunnhemp for green manuring and as fibre crops on the productivity and economics of rice-wheat cropping system in Uttar Pradesh. In Jute and allied fibres- agriculture and processing, edited by P.Palit, S. Pathak and D.P.Singh, Central Research Institute for Jute and Allied Fibre, Barrackpore, West Bengal
- Johnson H W, Robinson H, Comstock R (1955) Estimates of genetic and environmental variability in soybeans 1. Agronomy journal 47 (7):314-318
- Kanwar R, Singh H (1959) Manurial value of sunnhemp, its effect on soil composition, juice quality and yield of sugarcane. Indian J. Sug. Res. and Dev 3 (4):194-201
- Maruthi R, Kumar A A, Choudhary S, et al (2024) Diversity Assessment of Indian Sunnhemp (*Crotalaria juncea* L.) Accessions for Enhanced Biomass and Fibre Yield using Geographic Information System Approach. Legume Research: An International Journal 47 (3)
- Mondin M, Santos-Serejo J A, Aguiar-Perecin M L (2007) Karyotype characterization of *Crotalaria juncea* (L.) by chromosome banding and physical mapping of 18S-5.8 S-26S and 5S rRNA gene sites. Genetics and Molecular Biology 30 (1):65-72
- Panse V, Abraham T, Leelavathi C (1965) Green manuring of crops (Review of experimental results) ICAR Tech. Bulletin 2
- Tandon R K, Agrawal D C, Singh R P (1959) Sanai (*Crotalaria juncea*) as a dual-purpose cropping cane rotation. Indian Sug Res and Dev 3 (2):72-78
- Wright S (1921) Correlation and causation. Journal of Agricultural Research 20:557-580