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Correlation studies for green manuring traits in sunnhemp (*Crotalaria juncea* (L.))

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Abstract
Genotypic correlation and path coefficient analysis were used to determine the effect of various traits as components of biomass yield in thirty sunnhemp [*Crotalaria juncea* (L.)] genotypes. The thirty sunnhemp genotypes were evaluated at research farm of department of Genetics and Plant Breeding, Navsari Agricultural University, Navsari during kharif-2017. Randomized complete block design with three replicates was used for laying out the field experiments. Path coefficient analysis indicated the high positive direct effect of dry weight of root nodules per plant, days to fifty percent flowering, leaf length, root length, C:N ratio, primary branches per plant and leaf area on fresh weight of plant. These findings suggested that emphasis should be given on these traits for selecting elite genotypes and further breeding programme. The character plant height, internodes per plant, stem diameter, root nodules per plant and fresh weight of root nodules per plant exhibited negative direct effects on fresh weight of plant.

Keywords: Green manuring traits, sunnhemp, *Crotalaria juncea* (L.)

Introduction
Sunnhemp (2n=16) is an important rotational crop. The major advantage of this crop is being a legume it has potential to fix atmospheric nitrogen. The bacteriods located in the nodules in the root help in nitrogen fixation and they are good for soil renovation. Sunnhemp crop is used in rotation with other crops like tobacco, potato and other crops which are having problem of nematode infection. The crop is also used in rotation with crops like wheat, sugarcane, rice and jute. In crops like tea, citrus, rubber and coconut, sunnhemp is used as a cover crop.
Sunnhemp is mainly cultivated as green manure and fibre crop and to an extent as fodder in certain parts of the country (Andhra Pradesh, Uttar Pradesh and Tamil Nadu). It is fed to the cattle as green and also as hay. Due to fast growing nature of sunnhemp it can yield two crops (if cut 30 cm from the ground) when it can out yield lucerne in India. Another important feature of sunnhemp is that when it is grown as fibre, the top portion can be used as fodder or hay after mixing with paddy straw. Nutritive value of sunnhemp was in no way less than berseem and lucerne. The feeding quality of mixed fodders (paddy straw and sunnhemp hay) found to be better than paddy straw alone.

Material and Methods
Evaluation of thirty genotypes was conducted at research farm of department of Genetics and Plant Breeding, Navsari Agricultural University, Navsari during kharif-2017. Three meter row of each genotype was grown at a spacing of 30×10 cm^2 in three replications following randomized block design. Thirteen quantitative traits *viz*., days to fifty percent flowering, plant height (cm), internodes per plant, primary branches per plant, stem diameter (cm), leaf length (cm), leaf area (cm^2), root length (cm), C:N ratio, root nodules per plant, fresh weight of root nodules per plant (g), dry weight of root nodules per plant (g) and fresh weight of plant was studied and observations was recorded. The statistical analysis was done in windostat software to interpret the data.
The correlation coefficient was worked out to determine the degree of association of a character with biomass yield and also among its components. The mean values were used to calculate the phenotypic correlation by using the formula given by Hazel (1943) [3]. The genotypic and phenotypic correlation coefficients were tested against standardized tabulated significant values of r with (g-2) degrees of freedom as per the procedure suggested by Fisher and Yates (1963) [2]. Path analysis was carried out by using both phenotypic and genotypic correlation coefficients to know the direct and indirect effects of the components on yield as suggested by Wright (1921) [8] and illustrated by Dewey and Lu (1959) [1].

Result and Discussion

Biomass yield is considered a very complex character as it is an interaction of number of factors inherent to plants and the environment in which it is grown. Hence, correlation coefficient analysis is widely used to measure the degree and direction of relationship between various traits and biomass yield. In the present study, genotypic correlation coefficient between thirteen pairs of traits were calculated

(Table 1). Highly positive genotypic correlations ($P \leq 0.01$) were detected for C:N ratio, internodes per plant and days to 50% flowering while positive significant correlation with plant height at genotypic level. Similar results were also obtained Virdi *et al.* (2006b) [7] for plant height. So more emphasis should be given to these characters during selection for higher green biomass yield.

Green biomass yield is a complex character as it is the multiplicative end product of several component traits. The characters contribute directly and also indirectly through other characters to the final biomass yield. The analysis of such interplay is done through path coefficient analysis, an account of which is given below (Table 2). The results indicated that fresh weight of plant was positively and directly affected by days to 50% flowering (0.7122), primary branches per plant (0.2327), leaf length (0.6363), leaf area (0.0750), root length (0.6117), C:N ratio (0.4785) and Dry weight of root nodules per plant (1.3203). Except fresh weight of root nodules per plant, all other above mentioned traits have positive correlation with biomass yield. The great influence of these traits reflected their importance for biomass yield improvement.

The highest positive direct effect was recorded by dry weight of root nodules per plant, days to 50% flowering and leaf length. These results are in accordance with the reports of Singh *et al*. (2004) [6] for days to 50% flowering. Days to 50% flowering had positive and highly significant genotypic correlation with fresh weight of plant and had positive direct effect on fresh weight of plant. Similar result was also reported by Nath and Tajane (2014) [4]. The genotypic correlation between plant height and fresh weight of plant was positive and significant. Its direct effect on fresh weight of plant was negative. Similar result was also reported by Sawarkar *et al*. (2014) [5].

The genotypic correlation between internodes per plant and fresh weight was positive and highly significant. Its direct effect on fresh weight of plant was negative. Its positive indirect effect on fresh weight of plant through days to 50% flowering, primary branches per plant, leaf area, root length, C:N ratio and dry weight of root nodules per plant. Its indirect contribution to plant height, stem diameter, leaf length, root nodules per plant and fresh weight of root nodules per plant was negative.

The genotypic correlation primary branches per plant and fresh weight of plant was positive. Its direct effect on fresh weight of plant was positive. Its positive indirect effect on fresh weight of plant through leaf area, root length, C:N ratio and dry weight of root nodules per plant. Its indirect contribution to days to 50% flowering, plant height, internodes per plant, stem diameter, leaf length, root nodule per plant and fresh weight of root nodules per plant was negative.

The genotypic correlation between stem diameter and fresh weight of plant was positive. Its direct effect on fresh weight of plant was negative. Its positive indirect effect on fresh weight of plant through days to 50% flowering, primary branches per plant, leaf length, leaf area, root length, C:N ratio and dry weight of root nodules per plant. Its indirect contribution to plant height, internodes per plant, root nodules per plant and fresh weight of root nodules per plant was negative.

The genotypic correlation between leaf length and fresh weight of plant was positive. Its direct effect on fresh weight of plant was positive. Its positive indirect effect on fresh weight of plant through internodes per plant, root length, C:N ratio, root nodules per plant and fresh weight of root nodules per plant. Its indirect contribution to days to 50% flowering, plant height, primary branches per plant, stem diameter, leaf area and dry weight of root nodules per plant was negative.

The genotypic correlation between leaf area and fresh weight of plant was positive. Its direct effect on fresh weight of plant was positive. Its positive indirect effect on fresh weight of plant through through days to 50% flowering, primary branches per plant, root length, C:N ratio and dry weight of root nodules per plant. Its indirect contribution to plant height, internodes per plant, stem diameter, leaf length, roots nodules per plant and fresh weight of root nodules per plant was negative.

The genotypic correlation between root length and fresh weight of plant was positive. Its direct effect on fresh weight of plant was positive. Its positive indirect effect on fresh weight of plant through primary branches per plant, leaf length, leaf area, C:N ratio, fresh weight of root nodules per plant and dry weight of root nodules per plant. Its indirect contribution to days to 50% flowering, plant height, internodes per plant, stem diameter and root nodules per plant was negative.

The genotypic correlation between C:N ratio and fresh weight of plant was positive and highly significant. Its direct effect on fresh weight of plant was positive. Its positive indirect effect on fresh weight of plant through primary branches per plant, leaf length, leaf area, root length and dry weight of root nodules per plant. Its indirect contribution to days to 50% flowering, plant height, internodes per plant, stem diameter, root nodules per plant and fresh weight of root nodules per plant was negative.

The genotypic correlation between root nodules per plant and fresh weight of plant was negative. Its direct effect on fresh weight of plant was negative. Its positive indirect effect on fresh weight of plant through days to 50% flowering, primary branches per plant, leaf area, root length, C:N ratio and dry weight of root nodules per plant. Its indirect contribution plant height, internodes per plant, stem diameter, leaf length and fresh weight of root nodules per plant was negative.

The genotypic correlation between fresh weight of root nodules per plant and fresh weight of plant was negative. Its direct effect on fresh weight of plant was negative. Its positive indirect effect on fresh weight of plant through days to 50% flowering, primary branches per plant, leaf area, C:N ratio and dry weight of root nodules per plant. Its indirect contribution to plant height, internodes per plant, stem diameter, leaf length, root length and root nodules per plant was negative.

The genotypic correlation between dry weight of root nodules per plant and fresh weight of plant was positive. It had high direct effect on fresh weight of plant was positive. Its positive indirect effect on fresh weight of plant through days to 50% flowering, primary branches per plant, leaf area, root length and C:N ratio. Its indirect contribution to plant height, internodes per plant, stem diameter, leaf length, root nodules per plant and fresh weight of root nodules per plant was negative. Thus it could be suggested that direct selection for this traits would bring about increment in fresh weight of plant.

Most of the traits are not studied by earlier researchers as they did not considered green biomass yield as the main trait and therefore reviews are not available.

Conclusion

From the results of present study it was revealed that for most of the characters studied there was higher degree of genotypic correlation coefficients than the phenotypic correlation coefficients, suggesting that there is a higher degree of association existing between two characters at genotypic level while the low phenotypic association suggested the influence of environment is playing a vital role on the characters. The correlation among various traits may result due to linkage, pleiotropy or physiological associations among characters. In case of a population which is obtained from crosses between diverse lines, linkage is a probable reason for correlation among the traits. The correlation is an effect of the segregating genes, if some of the genes effect is increasing both the characters manifest the positive correlation, while if one gene effect is increasing and the other gene effect is decreasing it may lead to negative correlation (Falconer, 1981). So, to know the maximum number of yield contributing characters for a single genotype, it is important to know the effect of the interrelationship of various characters contributing towards yield. From the present investigation it was known that the fresh weight of plant was found to be positively and highly significantly correlated with days to 50% flowering, internodes per plant and C:N ratio while positively and significantly correlated with plant height. Frm the path coefficient analysis of different characters it was manifested that the highest positive direct effect was recorded by dry weight of root nodules per plant, days to 50% flowering and leaf length. Therefore, selection pressure on these characters may be given due importance for genetic improvement. Characters like plant height and internodes per plant exhibited negative direct effect but positive correlation on biomass yield. In the present study, overall result of path analysis showed that for improving green biomass in sunnhemp, selection advantage should be given to dry weight of root nodules per plant, days to 50% flowering and root length. In spite of this, preference of consumer must be taken into consideration during selection of the traits.

Table 1: Genotypic and phenotypic correlation coefficients of fresh weight with other characters in sunnhemp

Characters	C	PH	IN	PBP	SD	LL	LA	RL	CNR	RN	FWN	DWN	FWP
DFF	r_g	0.036	0.594^{**}	-0.101	0.285	-0.320^{**}	0.358^{**}	-0.256^{*}	-0.037	0.325^{**}	0.330^{**}	0.378^{**}	0.287^{**}
	r_p	0.050	0.316^{**}	-0.050	0.085	-0.205	0.157	-0.257^{*}	-0.020	0.292^{**}	0.290^{**}	0.338^{**}	0.235
PH	r_g		0.058	0.452^{**}	0.774	0.082	1.128^{**}	1.027^{**}	0.759^{**}	0.328^{**}	0.157	0.329^{**}	0.257^{*}
	r_p		0.336^{**}	0.325^{**}	0.029	0.183	0.366^{**}	0.395^{**}	0.431^{**}	0.195	0.078	0.217^{*}	0.064
IN	r_g			0.420	0.437	-0.482^{**}	0.252^{*}	0.090	0.363^{**}	0.387^{**}	0.317^{**}	0.456^{**}	0.344^{**}
	r_p			0.190	-0.139	-0.015	0.326^{**}	-0.040	0.161	0.195	0.158	0.289^{**}	0.034
PBP	r_g				0.345	-0.469^{**}	0.909^{**}	0.480^{**}	0.739^{**}	0.338^{**}	0.051	0.208^{*}	0.0001
	r_p				-0.023	0.012	0.372^{**}	0.108	0.231^{*}	0.060	0.014	0.131	-0.041
SD	r_g					0.129	1.011	0.380^{**}	0.650^{**}	0.459^{**}	0.454^{**}	0.530^{**}	0.112
	r_p					0.034	0.152	0.151	0.161	0.124	0.126	0.186	0.104
LL	r_g						-0.497^{**}	0.188	0.085	-0.374^{**}	-0.418^{**}	-0.412^{**}	0.178
	r_p						-0.104	0.108	0.091	-0.278^{**}	-0.323^{**}	-0.213^{*}	0.178
LA	r_g							0.691^{**}	0.914^{**}	0.745^{**}	0.713^{**}	0.803^{**}	0.019
	r_p							0.111	0.278^{**}	0.285^{**}	0.269^{*}	0.389^{**}	-0.056
RL	r_g								0.634^{**}	0.045	-0.085	0.025	0.138
	r_p								0.292^{**}	-0.052	-0.042	0.054	0.135
CNR	r_g									0.227^{*}	0.198	0.385^{**}	0.541^{**}
	r_p									0.091	0.132	0.274^{**}	0.334
RN	r_g										0.896^{**}	0.987^{**}	-0.030
	r_p										0.812^{**}	0.845^{**}	-0.055
FWN	r_g											0.937^{**}	-0.062
	r_p											0.850^{**}	-0.046
DWN	r_g												0.011
	r_p												0.034

*, **Significant at P=0.05 level and P=0.01 level
DFF= Days to 50% flowering
PH= Plant height (cm)
RL= Root length (cm)
SD= Stem diameter (cm)
C= Correlation
IN= Internodes per plant
PBP= Primary branches per plant
LL= Leaf length (cm)
LA=Leaf area
RN= Root nodules per plant
FWN=Fresh weight of root nodules per plant (g)
DWN= Dry weight of root nodules per plant (g)
FWP= Fresh weight of plant (g)
CNR= C:N ratio

Table 2: Genotypic path coefficient analysis showing direct and indirect effects of different characters on fresh weight of plant in sunnhemp

Characters	DFF	PH	IN	PBP	SD	LL	LA	RL	CNR	RN	FWN	DWN
DFF	0.7122	0.0232	0.4233	-0.0718	0.2028	-0.2272	0.2550	-0.1823	-0.0260	0.2315	0.2352	0.2692
PH	-0.0208	-0.6362	-0.0368	-0.2873	-0.4921	-0.0522	-0.7174	-0.6531	-0.4825	-0.2088	-0.1001	-0.2092
IN	-0.0014	-0.0001	-0.0024	-0.0010	-0.0010	0.0011	-0.0006	-0.0002	-0.0009	-0.0009	-0.0008	-0.0011
PBP	-0.0234	0.1051	0.0978	0.2327	0.0802	-0.1092	0.2115	0.1116	0.1719	0.0786	0.0120	0.0483
SD	-0.1590	-0.4319	-0.2440	-0.1925	-0.5584	-0.0716	-0.5643	-0.2122	-0.3629	-0.2562	-0.2533	-0.2960
LL	-0.2030	0.0522	-0.3065	-0.2986	0.0816	0.6363	-0.3161	0.1195	0.0540	-0.2376	-0.2660	-0.2619
LA	0.0269	0.0846	0.0189	0.0682	0.0758	-0.0373	0.0750	0.0519	0.0686	0.0559	0.0535	0.0603
RL	-0.1566	0.6280	0.0551	0.2934	0.2325	0.1149	0.4229	0.6117	0.3881	0.0276	-0.0520	0.0152
CNR	-0.0175	0.3630	0.1738	0.3536	0.3110	0.0406	0.4375	0.3036	0.4785	0.1084	0.0946	0.1841
RN	-0.3543	-0.3578	-0.4223	-0.3685	-0.5003	0.4071	-0.8127	-0.0491	-0.2469	-1.0903	-0.9766	-1.0756
FWN	-0.0150	-0.0071	-0.0144	-0.0023	-0.0205	0.0189	-0.0323	0.0038	-0.0090	-0.0406	-0.0453	-0.0424
DWN	0.4990	0.4342	0.6015	0.2742	0.6999	-0.5435	1.0606	0.0328	0.5078	1.3025	1.2364	1.3203
Correlation with FWP	0.2872**	0.257*	0.344**	0.0001	0.112	0.178	0.019	0.138	0.541**	-0.030	-0.062	0.011

*, **Significant at P =0.5 and 0.01 level. Residual effect =0.7170. Bold figures show direct effect

DFF= Days to 50% flowering
PH= Plant height (cm)
RL= Root length (cm)
SD= Stem diameter (cm)
IN= Internodes per plant
PBP= Primary branches per plant
LL= Leaf length (cm)
LA=Leaf area
RN= Root nodules per plant
FWN=Fresh weight of root nodules per plant (g)
DWN= Dry weight of root nodules per plant (g)
FWP= Fresh weight of plant (g)
CNR= C:N ratio

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