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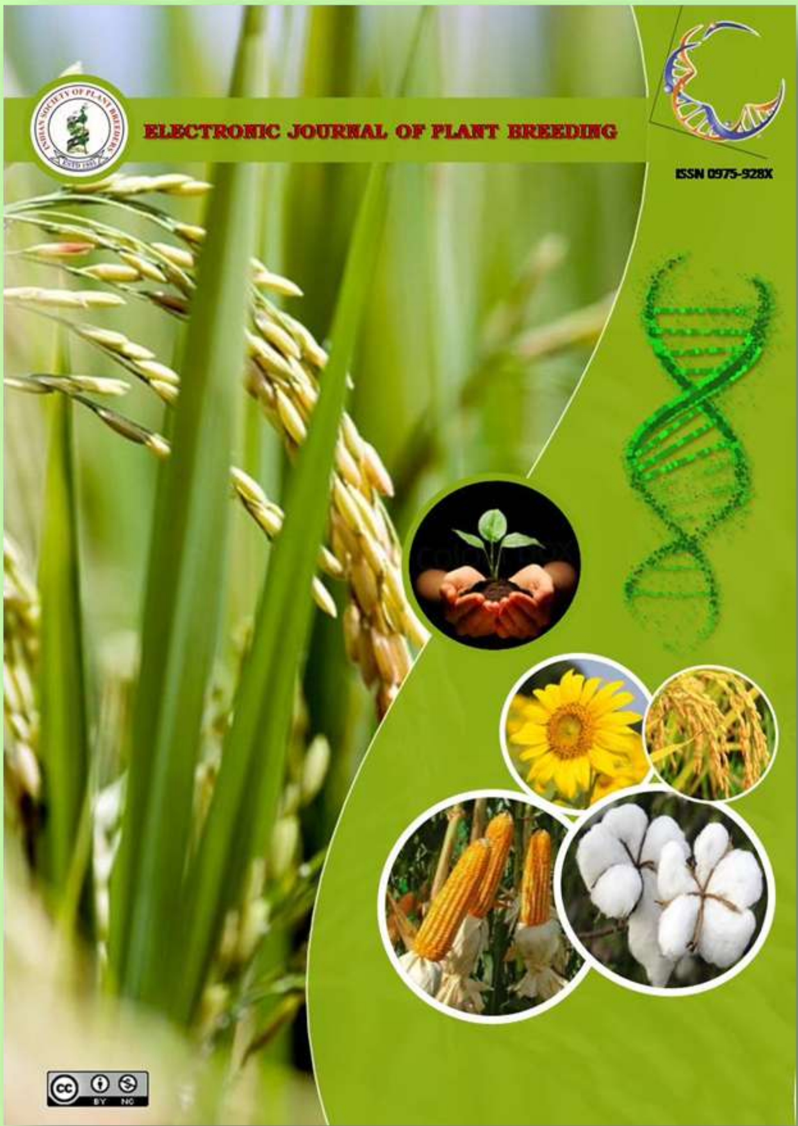

ISSN: 0975-928X

Volume: 10

Number:2

EJPB (2019) 10(2):720-726

DOI:10.5958/0975-928X.2019.00093.0

Electronic Journal of Plant Breeding, 10 (2): 720-726 (Jun 2019) DOI: 10.5958/0975-928X.2019.00093.0
ISSN 0975-928X

Research Article

Studies on interrelationship and path coefficient analysis of fodder yield and yield component traits in fodder cowpea (*Vigna ungiculata* L. Walp)

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(Received:15 Apr 2019; Revised:17 May 2019; Accepted:31 May 2019)

Abstract
An experiment was carried out to assess the nature and magnitude of association among 11 quantitative traits in 136 fodder cowpea accessions. From correlation studies, it is evident that the traits *viz.,* number of primary branches per plant, number of leaves per plant and leaf area exhibited significant positive correlation towards green fodder yield per plant as well as dry matter yield per plant. The highest positive direct effect of leaf area and the highest positive indirect effects of number of leaves per plant and dry matter yield per plant *via* leaf area would contribute more towards increasing green fodder yield per plant. Thus the traits *viz.,*number of primary branches per plant, number of leaves per plant, leaf area and dry matter yield per plant could be opted as selection index for fodder yield improvement in cowpea.

Key words
Correlation, Path coefficient analysis, Fodder cowpea

Introduction

Fodder cowpea (*Vigna ungiculata* L. Walp) is considered as one of the predominant leguminous fodder crops because of its high biomass yield of 23.4 t/ha (Etana *et al.*, 2013), high protein content up to 26% (Relwani *et al.*, 1970) and quick growing nature (Singh *et al.*, 2003). It is a warm weather annual herbaceous legume (Sahai *et al.*, 2013)having an ideal growth temperature of 23^{o}C to 32.5^{o}C (Craufurd *et al.*, 1996). This is the crop that is primarily cultivated in two seasons *viz.*, as a rainfed crop during *Kharif*(Vir and Singh, 2014)and as an irrigated crop during summer(Etana *et al.*, 2013). Cowpea is mainly grown as an ideal crop in the semi-arid and humid regions of the tropics (Shanko *et al.*, 2014)where it comes well in all types of soils particularly in well-drained sandy loam to clay loam soils with the pH ranging between 6 and 7 (Dugje *et al.*, 2009). The green fodder can be obtainable from 50-55 days after sowing (Babu *et al.*, 2016)and thereby minimizing the demand on fodder crops during lean seasons(Singh *et al.*, 2010). The crop is shade tolerant(Singh *et al.*, 2003)and perhaps it can be raised as a mixed crop with maize (*Zea mays* L.) and sorghum (*Sorghum bicolor* L. Moench) to feed animals with optimal cereal and legume fodder mixture (Singh *et al.*, 2010). The nutritive value of fodder cowpea is highly valued due to its low fibre content, high feeding efficiency and digestibility and minor level of anti-nutritional and flatulence inducing factors. In accordance with Singh *et al.* (2018), crude protein content, neutral detergent fibre and lignin proportions of fodder cowpea cultivars varied at 22.23-23.41%, 50.54-55.10% and 8.48-10.76%, respectively. Moreover, the crop has smothering effect, drought lenient attribute and soil rehabilitating ability by checking erosion (Lesly, 2005). The crop forms a valuable component in traditional cropping systems by acting as a soil fertility restorer through atmospheric nitrogen fixation for subsequent crops (Carsky and Vanlauwe, 2002). It is reported that cowpea fixes atmospheric nitrogen up to 240 kg/ha and leaves about 60-70 kg nitrogen for subsequent crops(Aikins and Afuakwa, 2008). In India, the land cover under fodder cowpea production is around 3 lakh hectares with the green fodder production efficiency of 25-45 t/ha (Bhagmal *et al.*, 2009).

Yield, a complex trait largely depends on the influence of numerous yield component characters which are governed by polygenes and also highly affected by environmental factors. Opting for direct selection towards green fodder yield alone is hardly productive and henceforth a clear understanding on the association of desirable yield component attributes with yield is crucial to make the selection process the most suitable and accurate. Correlation coefficient analysis is an easy technique that aids in determining the degree and magnitude of association between yield and its component characters. This analysis has its significance in selection technique if the desirable choice of yield associated characters are highly heritable

(Manggoel *et al.*, 2012). However, it often misleads if high significant correlation between two characters is due to the indirect effect of other characters (Bizeti *et al.*, 2004). Hence, path coefficient analysis splits and quantifies the correlation coefficient into direct and indirect effects of a number of independent characters on a dependent character. Dewey and Lu (1959) were the first to apply for selection in plants to study the nature of associations among various characters in crested wheatgrass and thereby suggesting suitable selection procedures.

Materials and Methods

A field trial was conducted at New Area Farm, Department of Forage Crops, Tamil Nadu Agricultural University (TNAU), Coimbatore during *Kharif*2018. The area comes under humid tropical climate with an average annual rainfall of 674.2 mm and a year-round minimum and maximum temperature of 21^{o}C and 31.5^{o}C, respectively (ACRC-TNAU). The soil is characterized by black grey colour and sandy clay texture with a pH of 7.94 in the 0-30 cm soil depth. The total nitrogen, phosphorus and potassium contents were 0.031%, 0.043% and 0.40%, respectively. The experimental material included 136 diverse fodder cowpea accessions being maintained at Department of Forage Crops, TNAU. The germplasm was raised in a Randomized Block Design with two replications. Each genotype in each replication was constituted by a row of 4 m length with a spacing of 60 cm x 15 cm. The standard package of practices was followed for proper establishment of the crop.

Observations were documented on 11 quantitative traits *viz.*, plant height (cm), number of primary branches per plant, days to 50% flowering, days to maturity, number of leaves per plant, leaf area (cm^2), green fodder yield per plant (g), dry matter yield per plant (g), crude protein content (%), crude fibre content (%) and crude fat content (%). Exempting the trait - days to maturity, all the observations were recorded at the 50% flowering stage. The genotypic and phenotypic correlation coefficient analysis of all the characters were formulated as per the method proposed by Singh and Chaudhary (1979)and computation of path coefficients at genotypic and phenotypic levels were done as recommended by Dewey and Lu (1959). The data was computed using the statistical package Indostat version 7.1 program.

Results and Discussion

The accomplishment of obtaining higher yield response through yield component characters in any crop breeding programme rely on understanding the degree and magnitude of interdependence amongst different yield characters. Green fodder yield is the outcome of association of various yield constituent characters which positively or negatively influence green fodder yield itself. This being the case, the selection should be made for yield constituent characters which are significantly and positively associated with green fodder yield. In correlation studies, choice for one attribute aids in improvement of other positively correlated attributes.

The assessment of genotypic (r_g) and phenotypic (r_p) correlation coefficients between different characters is presented in Table 1. In most of the occurrences, the genotypic correlation coefficients were higher in values when compared to phenotypic correlation coefficients suggesting the minimal pressure in the expression of character association by surrounding factors(Singh *et al.*, 2010). It was found that green fodder yield per plant exhibited significant positive correlation with number of primary branches per plant (r_g = 0.2190, r_p = 0.1723)(Dangi and Paroda, 1974; Sheela and Gopalan, 2006), number of leaves per plant (r_g= 0.9708, r_p = 0.9478)(Dangi and Paroda, 1974; Sahai *et al.*, 2013; Sheela and Gopalan, 2006), leaf area (r_g = 0.9892, r_p = 0.9804) (Sanusi and Lawan, 2010)and dry matter yield per plant (r_g= 0.7720, r_p = 0.7253) (Singh *et al.*, 2010)at both genotypic and phenotypic levels while the quality attribute crude fibre content (r_g = 0.1720) showed significant positive correlation at genotypic level only. None of the characters expressed negative significant correlation towards green fodder yield per plant.

With regard to dry matter yield per plant, characters *viz.*, number of leaves per plant (r_g = 0.7169, r_p = 0.6679), leaf area (r_g = 0.7443, r_p = 0.6962) and green fodder yield per plant (r_g = 0.7720, r_p = 0.7253)evidenced highly significant positive correlation at both the levels while number of primary branches per plant (r_g = 0.2120) exhibited significant positive correlation at genotypic level alone. Similarly, significant positive correlation of dry matter yield per plant with number of leaves per plant and green fodder yield per plant were reported by Chopra and Singh (1977); Dangi and Paroda (1974); Sahai *et al.* (2013); Sheela and Gopalan (2006).

Perceiving the knowledge on interrelationship between characters, guides plant breeders towards selection of related characters for crop enhancement. Characters *viz.*, number of primary branches per plant exhibited significant positive inter-correlation with plant height (r_g = 0.3748, r_p = 0.3385), number of leaves per plant (r_g = 0.2123, r_p = 0.1721), leaf area (r_g = 0.2342, r_p = 0.1868) and crude fibre content (r_g = 0.1757) while number of leaves per plant showed significant positive inter-correlation with leaf area (r_g = 0.9757, r_p = 0.9568), crude fibre content (r_g = 0.1979, r_p = 0.1777) and crude fat content(r_g = 0.1811).The present findings are on par with that of Dangi and Paroda (1974); Imran *et al.* (2010); Sheela and Gopalan (2006). Days to 50% flowering was highly significant and positively correlated with days to maturity (r_g = 0.9997, r_p = 0.9423) but showed non significance with other yield characters. This is in accordance with the inference as observed by Bashir *et al.* (2001). The quality character crude protein content was significant but negatively correlated with plant height (r_g = -0.1961, r_p = -0.1906), crude fibre content (r_g = -0.2555, r_p = -0.2510) (Dangi and Paroda, 1974)and crude fat content (r_g = -0.2170, r_p = -0.2040) at both the levels.

Correlation coefficients assists entirely in determining the bilateral association between two variables or characters. However, they don't provide the exact information on the complex relationship that exists among a set of variables or characters with respect to yield. Path coefficient analysis unravels this complex relationship that prevails among a group of yield attributing characters by partitioning the correlation coefficients into the measures of direct and indirect effects and aids in quantifying their contribution towards yield. Green fodder yield in cowpea is the totality of a number of yield component factors which directly or indirectly contributes to it and path analysis depicts a clear picture to estimate the nature and magnitude of different yield component factors towards green fodder yield.

The direct and indirect effects of 10different characters against green fodder yield per plant at genotypic and phenotypic levels isgiven in Table2. The trait leaf area (r_g = 1.0294, r_p= 0.8256) recorded the highest positive direct effect with green fodder yield per plant at both genotypic and phenotypic levels. Direct effect of number of leaves per plant (r_g = -0.0459, r_p = 0.1120) and dry matter yield per plant (r_g = 0.0503, r_p = 0.0823) towards green fodder yield per plant was negligible and negative (Sheela and Gopalan, 2006)at both the levels but exorbitant positive indirect effects through leaf area (r_g = 1.0044, r_p = 0.7899 and r_g = 0.7662, r_p = 0.5747 respectively) contributed towards greater significant correlation with green fodder yield per plant. The residual effect (r_g= 0.1374, r_p= 0.1808)states that the traits which were studied in path coefficient analysis at genotypic and phenotypic levels were sufficient and relevant.

The direct and indirect effects of 10 various traits on dry matter yield per plant obtained from path coefficient analysis at genotypic and phenotypic levels is represented in Table 3. At genotypic level, characters *viz.*, green fodder yield per plant (r_g= 1.2642) registered high positive direct effect with dry matter yield per plant followed by number of leaves per plant (r_g = 0.8702) and number of primary branches per plant (r_g = 0.1564).The results are in partial agreement with that of Chopra and Singh (1977); Dangi and Paroda (1974). The positive and high indirect effects of number of leaves per plant (r_g = 1.2272) and leaf area (r_g = 1.2506) *via* green fodder yield per plant responded well towards significant positive correlation for dry matter yield per plant than their corresponding direct effects. Though the positive direct effect of days to maturity (r_g = 5.9234) and its positive indirect effect *via* days to 50 per cent flowering (r_g = 5.9216) on dry matter yield per plant recorded the highest, there exists no significant correlation towards dry matter yield per plant. With reference to phenotypic level, green fodder yield per plant (r_p = 1.1245) showed the highest direct effect for dry matter yield per plant while the estimates of all other traits were small and negative. In similar way to genotypic level, trends for significant positive correlation in dry matter yield per plant at phenotypic level was due to the indirect effects of number of leaves per plant (r_p = 1.0658) and leaf area(r_p = 1.1024) through green fodder yield per plant as direct effects of those traits showed negative. The residual effects of dry matter yield per plant at genotypic (r_g= 0.6884) and phenotypic (r_p= 0.6683) levels were high indicating that still more number of characters have to be included for estimation.

It was evident from correlation studies that characters *viz.*, number of primary branches per plant, number of leaves per plant and leaf area exhibited significant positive correlation with green fodder yield per plant as well as dry matter yield per plant. The highest positive direct effect of leaf area and the highest positive indirect effects of number of leaves per plant and dry matter yield per plant through leaf area would contribute more towards increasing green fodder yield per plant. Hence, with this wide range of accessions used under this study, more emphasis could be given on the above traits to use as selection indexin crop improvement programme to substantially improve green fodder yield in cowpea.

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Electronic Journal of Plant Breeding, 10 (2): 720-726 (Jun 2019) DOI: 10.5958/0975-928X.2019.00093.0
ISSN 0975-928X

Table 1. Assessment of genotypic (r_g) and phenotypic (r_p) correlation coefficients between different characters in 136 fodder cowpea accessions

Characters		NPB	DFF	DTM	NOL	LAR	CPR	CFB	CFT	DMY	GFY
PHT	r_g	0.3748**	0.0570	0.0375	0.1295	0.1153	-0.1961*	0.1323	0.1262	0.0498	0.1208
	r_p	0.3385**	0.0484	0.0382	0.1146	0.1088	-0.1906*	0.1215	0.1200	0.0500	0.1137
NPB	r_g		-0.0680	-0.0770	0.2123*	0.2342**	-0.0699	0.1757*	0.0576	0.2120*	0.2190*
	r_p		-0.0676	-0.0693	0.1721*	0.1868*	-0.0653	0.1647	0.0469	0.1697	0.1723*
DFF	r_g			0.9997**	-0.0132	0.0029	-0.0260	-0.1232	-0.0610	-0.0866	0.0009
	r_p			0.9423**	-0.0145	0.0059	-0.0241	-0.1127	-0.0545	-0.0820	0.0080
DTM	r_g				0.0018	0.0279	-0.0423	-0.1052	-0.0499	-0.0818	0.0258
	r_p				0.0022	0.0308	-0.0407	-0.1048	-0.0403	-0.0800	0.0250
NOL	r_g					0.9757**	-0.0395	0.1979*	0.1811*	0.7169**	0.9708**
	r_p					0.9568**	-0.0352	0.1777*	0.1709	0.6679**	0.9478**
LAR	r_g						-0.0158	0.2005*	0.1660	0.7443**	0.9892**
	r_p						-0.0169	0.1868*	0.1553	0.6962**	0.9804**
CPR	r_g							-0.2555**	-0.2170*	-0.0748	-0.0158
	r_p							-0.2510**	-0.2040*	-0.0670	-0.0175
CFB	r_g								-0.0095	0.1470	0.1720*
	r_p								-0.0088	0.1375	0.1598
CFT	r_g									0.0608	0.1449
	r_p									0.0557	0.1353
DMY	r_g										0.7720**
	r_p										0.7253**

** Significant at 1% probability level = 0.223 * Significant at 5% probability level = 0.171
r_g- Genotypic correlation coefficients r_p- Phenotypic correlation coefficients

PHT - Plant height (cm), **NPB** - Number of primary branches per plant, **DFF** - Days to 50% flowering, **DTM** - Days to maturity,
NOL - Number of leaves per plant, **LAR** - Leaf area (cm^2), **CPR** - Crude protein content (%), **CFB** - Crude fibre content (%), **CFT** - Crude fat content (%), **DMY** - Dry matter yield per plant (g), **GFY** - Green fodder yield per plant (g).

Table 2. Assessment of direct (bold) and indirect effects of different characters against green fodder yield per plant at genotypic and phenotypic levels in 136 fodder cowpea accessions

Characters		PHT	NPB	DFF	DTM	NOL	LAR	CPR	CFB	CFT	DMY	GFY
PHT	r_g	**0.0010**	0.0004	0.0001	0.0000	0.0001	0.0001	-0.0002	0.0001	0.0001	0.0000	0.1208
	r_p	**0.0163**	0.0055	0.0008	0.0006	0.0019	0.0018	-0.0031	0.0020	0.0020	0.0008	0.1137
NPB	r_g	-0.0106	**-0.0283**	0.0019	0.0022	-0.0060	-0.0066	0.0020	-0.0050	-0.0016	-0.0060	0.2190*
	r_p	-0.0053	**-0.0157**	0.0011	0.0011	-0.0027	-0.0029	0.0010	-0.0026	-0.0007	-0.0027	0.1723*
DFF	r_g	0.0461	-0.0550	**0.8090**	0.8088	-0.0107	0.0024	-0.0210	-0.0996	-0.0494	-0.0701	0.0009
	r_p	0.0022	-0.0030	**0.0449**	0.0423	-0.0007	0.0003	-0.0011	-0.0051	-0.0024	-0.0037	0.0080
DTM	r_g	-0.0305	0.0626	-0.8132	**-0.8134**	-0.0015	-0.0227	0.0344	0.0856	0.0406	0.0665	0.0258
	r_p	-0.0016	0.0029	-0.0391	**-0.0415**	-0.0001	-0.0013	0.0017	0.0044	0.0017	0.0033	0.0250
NOL	r_g	-0.0059	-0.0097	0.0006	-0.0001	**-0.0459**	-0.0447	0.0018	-0.0091	-0.0083	-0.0329	0.9708**
	r_p	0.0128	0.0193	-0.0016	0.0003	**0.1120**	0.1071	-0.0039	0.0199	0.0191	0.0748	0.9478**
LAR	r_g	0.1187	0.2411	0.0030	0.0287	1.0044	**1.0294**	-0.0163	0.2064	0.1709	0.7662	0.9892**
	r_p	0.0898	0.1542	0.0049	0.0254	0.7899	**0.8256**	-0.0140	0.1543	0.1282	0.5747	0.9804**
CPR	r_g	0.0041	0.0015	0.0005	0.0009	0.0008	0.0003	**-0.0211**	0.0054	0.0046	0.0016	-0.0158
	r_p	0.0005	0.0002	0.0001	0.0001	0.0001	0.0000	**-0.0026**	0.0006	0.0005	0.0002	-0.0175
CFB	r_g	-0.0026	-0.0034	0.0024	0.0020	-0.0038	-0.0039	0.0049	**-0.0194**	0.0002	-0.0028	0.1720*
	r_p	-0.0031	-0.0041	0.0028	0.0026	-0.0045	-0.0047	0.0063	**-0.0252**	0.0002	-0.0035	0.1598
CFT	r_g	-0.0019	-0.0009	0.0009	0.0008	-0.0028	-0.0025	0.0033	0.0001	**-0.0152**	-0.0009	0.1449
	r_p	-0.0021	-0.0008	0.0010	0.0007	-0.0031	-0.0028	0.0036	0.0002	**-0.0179**	-0.0010	0.1353
DMY	r_g	0.0025	0.0107	-0.0044	-0.0041	0.0361	0.0375	-0.0038	0.0074	0.0031	**0.0503**	0.7720**
	r_p	0.0041	0.0140	-0.0068	-0.0066	0.0550	0.0573	-0.0055	0.0113	0.0046	**0.0823**	0.7253**

R square (r_g= 0.9811, r_p= 0.9673) Residual effect (r_g= 0.1374, r_p= 1808)
** Significant at 1% probability level = 0.223 * Significant at 5% probability level = 0.171

PHT - Plant height (cm), **NPB** - Number of primary branches per plant, **DFF** - Days to 50% flowering, **DTM** - Days to maturity,
NOL - Number of leaves per plant, **LAR** - Leaf area (cm^2), **CPR** - Crude protein content (%), **CFB** - Crude fibre content (%), **CFT** - Crude fat content (%), **DMY** - Dry matter yield per plant (g), **GFY** - Green fodder yield per plant (g).

Electronic Journal of Plant Breeding, 10 (2): 720-726 (Jun 2019) DOI: 10.5958/0975-928X.2019.00093.0
ISSN 0975-928X

Table 3. Assessment of direct (bold) and indirect effects of different characters against dry matter yield per plant at genotypic and phenotypic levels in 136 fodder cowpea accessions

Characters		PHT	NPB	DFF	DTM	NOL	LAR	CPR	CFB	CFT	GFY	DMY
PHT	r_g	**0.0495**	0.0186	0.0028	0.0019	0.0064	0.0057	-0.0097	0.0065	0.0062	0.0060	0.0498
	r_p	**-0.0592**	-0.0200	-0.0029	-0.0023	-0.0068	-0.0064	0.0113	-0.0072	-0.0071	-0.0067	0.0500
NPB	r_g	0.0586	**0.1564**	-0.0106	-0.0120	0.0332	0.0366	-0.0109	0.0275	0.0090	0.0342	0.2120*
	r_p	0.0205	**0.0605**	-0.0041	-0.0042	0.0104	0.0113	-0.0039	0.0100	0.0028	0.0104	0.1697
DFF	r_g	-0.3419	0.4080	**-6.0022**	-6.0004	0.0795	-0.0176	0.1558	0.7392	0.3662	-0.0057	-0.0866
	r_p	0.0015	-0.0021	**0.0317**	0.0298	-0.0005	0.0002	-0.0008	-0.0036	-0.0017	0.0003	-0.0820
DTM	r_g	0.2223	-0.4559	5.9216	**5.9234**	0.0109	0.1651	-0.2507	-0.6232	-0.2955	0.1526	-0.0818
	r_p	-0.0049	0.0089	-0.1204	**-0.1278**	-0.0003	-0.0039	0.0052	0.0134	0.0052	-0.0032	-0.0800
NOL	r_g	0.1127	0.1848	-0.0115	0.0016	**0.8702**	0.8491	-0.0344	0.1723	0.1576	0.8448	0.7169**
	r_p	-0.0155	-0.0232	0.0020	-0.0003	**-0.1351**	-0.1293	0.0048	-0.0240	-0.0231	-0.1281	0.6679**
LAR	r_g	-0.1740	-0.3536	-0.0044	-0.0421	-1.4728	**-1.5094**	0.0239	-0.3027	-0.2505	-1.4932	0.7443**
	r_p	-0.0296	-0.0509	-0.0016	-0.0084	-0.2605	**-0.2723**	0.0046	-0.0509	-0.0423	-0.2670	0.6962**
CPR	r_g	-0.0050	-0.0018	-0.0007	-0.0011	-0.0010	-0.0004	**0.0256**	-0.0065	-0.0056	-0.0004	-0.0748
	r_p	0.0148	0.0051	0.0019	0.0032	0.0027	0.0013	**-0.0778**	0.0195	0.0159	0.0014	-0.0670
CFB	r_g	-0.0112	-0.0149	0.0104	0.0089	-0.0168	-0.0170	0.0216	**-0.0846**	0.0008	-0.0146	0.1470
	r_p	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0001	**0.0002**	0.0000	0.0000	0.1375
CFT	r_g	-0.0140	-0.0064	0.0067	0.0055	-0.0200	-0.0184	0.0240	0.0011	**-0.1106**	-0.0160	0.0608
	r_p	-0.0055	-0.0022	0.0025	0.0019	-0.0079	-0.0071	0.0094	0.0004	**-0.0460**	-0.0062	0.0557
GFY	r_g	0.1528	0.2768	0.0012	0.0326	1.2272	1.2506	-0.0200	0.2174	0.1832	**1.2642**	0.7720**
	r_p	0.1278	0.1937	0.0090	0.0281	1.0658	1.1024	-0.0197	0.1797	0.1521	**1.1245**	0.7253**

R square (r_g= 0.5261, r_p= 0. 5534) Residual effect (r_g= 0.6884 r_p= 0.6683)
** Significant at 1% probability level = 0.223 * Significant at 5% probability level = 0.171

PHT - Plant height (cm), **NPB** - Number of primary branches per plant, **DFF** - Days to 50% flowering, **DTM** - Days to maturity,
NOL - Number of leaves per plant, **LAR** - Leaf area (cm^2), **CPR** - Crude protein content (%), **CFB** - Crude fibre content (%), **CFT** - Crude fat content (%), **GFY** - Green fodder yield per plant(g), **DMY** - Dry matter yield per plant (g).

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