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Research Note

Study on character association and path analysis in little millet (*Panicum sumatrense* L.)

Kinal Patel, Arna Das*, Dhrumi Dalsaniya, Arvind D. Kalola[2], Ghanshyam B. Patil[1], Rumit Patel, Dipak A. Patel[1], Harshal E. Patil[3]

Department of Genetics and Plant Breeding, B. A. College of Agricsulture, Anand Agricultural University, Anand, Gujarat - 388110
[1]Department of Agricultural Biotechnology, Anand Agricultural University, Anand, Gujarat - 388110
[2]Department of Agricultural Statistics, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat - 388110
[3]Hill Millet Research Station, Navsari Agricultural University, Waghai, Gujarat.
***E-Mail**: arna_das@aau.in

Abstract
Little millet (*Panicum sumatrense* L.) is one of the neglected crops which is becoming popular as nutri-cereal. Development of high yielding stable cultivars may offer better economic return from this crop. Assessment of inter-relationship among important economic traits helps to identify major yield component traits which could be selected for overall yield improvement hence development of superior genotypes. In this context, 50 genotypes of little millet were evaluated during *kharif* 2021, to identify important yield component traits through correlation and path analysis of 16 quantitative traits. Estimates of genotypic correlation coefficients were found to be higher than the estimates of phenotypic correlation coefficients, indicating that association were majorly under genetic control. It was revealed that direct selection based on fodder yield per plant, plant height and 1000 seed weight may help in augmenting grain yield in the experimental material, whereas, harvest index came out as the most important character for indirect selection.

Keywords: Little millet, Correlation, Path analysis, Yield components

Little millet (*Panicum sumatrense* Roth. ex. Roem. & Schult syn. *Panicum millare* auct. non Lam.) is an early maturing, self-pollinated allotetraploid (2n = 4x =36) belonging to the family Poaceae. It is one of the important small grain crops that grows well in arid and semi-arid climate with marginal practices. Little millet is indigenous to Indian sub- continent and is considered to be evolved from wild *Panicum psilopodium*. It is believed to be domesticated in the Eastern Ghats of India (Odisha and Andhra Pradesh) where it occupies a major share in tribal diet (Hiremath and Salimat, 1992; Paschapur *et al*., 2021). In India it is commonly known as samai, samo, moraio, vari, kutki and also some other names. Little millet is rich in good cholesterol which is suitable for growth and development. Its complex carbohydrate is digested slowly which is very helpful for diabetic patients (Gayathri, 2015; Selvi *et al*., 2015a). Its high fiber content along with high phosphorous, iron, protein, carbohydrate and fat have made it an ideal replacement for rice (Reddy, 2017), and is especially good for people having low body mass. Climatic requirements for little millet cultivation are very specific hence, only a few states in India, namely, Rajasthan, Karnataka, Madhya Pradesh, Uttar Pradesh, Tamil Nadu, Odisha, Andhra Pradesh and Gujarat could maintain sizable area under little millet cultivation (Kumar *et al*., 2021). In Gujarat, small millets including little millet are cultivated mainly in hilly tracts of the Southern districts.

Knowledge on character association for yield and its component characters is essential while aiming yield improvement through selection. Vegetative characters which are positively associated with reproductive traits assist in selection at the early growth stage of crop. Unfavorable associations with desirable component traits may also be identified so as to avoid genetic slippage (Wang *et al*., 2011). Besides, path coefficient analysis is helpful to recognize direct and indirect association of traits and also enables comparison of causal factors for their relative contributions. Keeping the above facts in mind the present investigation was carried out to study the association between yield and its contributing traits in little millet.

A total of 50 different genotypes of little millet were collected from Hill Millet Research Station, Navsari Agricultural University, Waghai, Gujarat. The field experiment was conducted in randomized block design with three replications at the Experimental Farm of Department of Genetics & Plant Breeding, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat (22° 35' N, 72° 55' E, 45.01 meters above mean sea level), during *kharif*, 2021 with a spacing of 30 × 10 cm. All the recommended package of practices were followed to raise a good crop.

A total of 16 different quantitative parameters were recorded as described in DUS guidelines for little millet provided by Protection of Plant Varieties and Farmer's Rights (PPV & FR) Authority, India (https://www.plantauthority.gov.in/). Moreover, three biochemical parameters were also recorded for all the genotypes, *viz*., crude protein content (%), total carbohydrate (%) and total phenol (%).Genotypic correlation coefficients and phenotypic correlation coefficients were estimated following Hazel *et al*. (1943) and path coefficient analysis was carried out according to Wright, 1921.

All the genotypes differed significantly from one another as evident from analysis of variance (**Table 1**).

Correlation coefficients (genotypic and phenotypic) for 16 characters are presented in **Table 2**. Estimates of genotypic correlation coefficients (r_g) were found higher than the estimates of phenotypic correlation coefficients (r_p), indicating that the associations were majorly under genetic control, whereas environment was responsible for the few exceptions, where r_p estimates were either higher or equal to r_g *i.e.* between grain yield per plant and harvest index, peduncle length and total carbohydrate, peduncle length and total phenol, days to maturity and total phenol, and between total carbohydrate and total phenol. Similar findings of higher phenotypic correlation than genotypic correlation were reported by Shinde *et al.*(2018) and Suryanarayana and Sekhar, 2018 in little millet.

Table 1. Analysis of variance

S. No.	Characters	Mean Sum of Squares		
		Replication	Genotype	Error
	df	2	49	98
1	Number of basal tillers per plant	0.7406	17.2235**	0.5259
2	Days to 50% flowering	1447.4767	421.5869**	9.9324
3	Flag leaf blade length	0.3134	54.4893**	0.1240
4	Flag leaf blade width	0.0015	0.1967**	0.0018
5	Peduncle length	0.1462	33.1656**	0.0500
6	Number of productive tillers per plant	1.1261	14.1563**	0.4644
7	Panicle length	0.1015	143.0040**	0.4732
8	Plant height	20.7954	967.1025**	10.0942
9	Days to maturity	9.2067	405.5659**	2.9822
10	1000 seed weight	0.0221	0.4168**	0.0074
11	Grain yield per plant	0.1174	27.4078**	0.7168
12	Fodder yield per plant	25.0803	1034.2957**	8.3463
13	Harvest index	0.0949	48.6750**	0.3972
14	Total carbohydrate	0.0798	41.9026**	0.0550
15	Crude protein	0.0326	5.1429**	0.0195
16	Total phenol	0.0011	0.0011**	0.0011

** Significant at 1% level of significance

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Table 2. Genotypic and phenotypic correlation coefficients among 16 different characters in little millet

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	r_g	1.00															
	r_p	1.00															
2	r_g	0.12	1.00														
	r_p	0.11	1.00														
3	r_g	-0.22	0.27	1.00													
	r_p	-0.21**	-0.26**	1.00													
4	r_g	-0.04	0.31*	0.02	1.00												
	r_p	-0.03	0.29**	0.01	1.00												
5	r_g	-0.13	-0.21	0.32*	0.46**	1.00											
	r_p	0.12	-0.20**	0.31**	0.45**	1.00											
6	r_g	-0.27	-0.03	-0.03	-0.05	0.02	1.00										
	r_p	-0.26**	-0.02	-0.02	-0.04	0.01	1.00										
7	r_g	0.14	0.97**	-0.33*	0.26	-0.22	-0.03	1.00									
	r_p	0.12	0.90**	-0.31**	0.25**	-0.21**	-0.02	1.00									
8	r_g	0.04	-0.34*	0.14	0.19	0.37**	-0.22	-0.34*	1.00								
	r_p	0.03	-0.32**	0.13	0.18*	0.36**	-0.12**	-0.33**	1.00								
9	r_g	0.36*	-0.12	0.24	0.39**	0.38**	-0.17	-0.15	0.34*	1.00							
	r_p	0.33**	-0.11	0.23**	0.38**	0.37**	-0.16*	-0.13	0.33**	1.00							
10	r_g	-0.24	-0.30*	0.99**	0.02	0.30*	-0.04	-0.34*	0.14	0.23	1.00						
	r_p	-0.22**	-0.29**	0.98**	0.01	0.29**	-0.03	0.32**	0.13	0.22**	1.00						
11	r_g	0.34*	0.35*	-0.54**	0.21	-0.13	-0.21	0.39**	0.15	0.27	-0.55**	1.00					
	r_p	0.31**	0.33**	-0.52**	0.20*	-0.12	-0.20*	0.36**	0.14	0.26**	-0.53**	1.00					
12	r_g	0.43**	0.07	0.15	0.21	0.40**	-0.15	0.05	0.13	0.59**	0.15	0.31*	1.00				
	r_p	0.42**	0.06	0.14	0.20*	0.39**	-0.14	0.04	0.12	0.58**	0.14	0.30**	1.00				
13	r_g	0.17	-0.08	-0.32*	-0.33*	-0.42**	-0.05	-0.04	-0.09	-0.45**	-0.31*	-0.12	-0.75**	1.00			
	r_p	0.19*	-0.07	-0.31**	-0.32**	-0.41**	-0.04	-0.03	-0.08	-0.44**	-0.30**	-0.11	-0.74**	1.00			
14	r_g	0.24	0.08	0.04	0.12	0.13	-0.20	0.15	-0.05	0.25	0.04	0.07	0.25	-0.08	1.00		
	r_p	0.23**	0.07	0.03	0.11	0.12	-0.20*	0.14	-0.04	0.21**	0.03	0.06	0.24**	-0.07	1.00		
15	r_g	0.02	-0.26	-0.14	-0.22	-0.22	0.07	-0.17	-0.27	-0.19	-0.11	-0.12	-0.10	0.19	0.06	1.00	
	r_p	0.01	-0.25**	-0.13	-0.21**	-0.20*	0.06	-0.16*	-0.26**	-0.18*	-0.10	-0.11	-0.09	0.18*	0.05	1.00	
16	r_g	-0.22	-0.16	0.05	0.14	0.14	0.04	-0.16	0.04	0.17	0.05	0.17	0.04	-0.17	-0.02	-0.10	1.00
	r_p	-0.21**	-0.15*	0.04	0.13	0.12	0.03	-0.14	0.03	0.16*	0.04	0.16*	0.03	-0.16*	-0.02	-0.09	1.00

*, ** Significant at 5% and 1% level of significance, respectively
r_g = Genotypic correlation coefficient; r_p = Phenotypic correlation coefficient

1. Grain yield per plant 2. Number of basal tillers per plant 3. Days to 50% flowering 4. Flag leaf blade length 5. Flag leaf blade width 6. Peduncle length 7. Number of productive tillers per plant, 8. Panicle length 9. Plant height 10. Days to maturity 11. 1000 seed weight 12. Fodder yield per plant 13. Harvest index 14. Total carbohydrate 15. Crude protein 16. Total phenol

Grain yield was found to be positively and significantly correlated with plant height (r_g = 0.36 and r_p = 0.33), 1000 seed weight (r_g = 0.34 and r_p = 0.31) and fodder yield per plant (r_g = 0.43 and r_p = 0.42) both at genotypic and phenotypic levels. The association of grain yield was positive but insignificant with number of basal tillers per plant (r_g = 0.12 and r_p = 0.11), number of productive tillers per plant (r_g = 0.14 and r_p = 0.12), panicle length (r_g = 0.04 and r_p = 0.03) and crude protein content (r_g = 0.02 and r_p = 0.01). Such positive association suggested that increase in one component character will increase grain yield per plant in little millet. Some of the characters had positive association with grain yield either at genotypic or at phenotypic level only. Negative association of grain yield with component traits suggested improvement in that character will decrease the grain yield per plant in little millet. The major yield components as revealed from the correlation study, *viz*., 1000 seed weight, fodder yield per plant, number of basal tillers per plant and number of productive tillers per plant had positive association amongst themselves indicating that selection for one character will contribute in improvement of all the other major component characters and overall yield. It was observed that plant height was associated with plants with lengthier and wider flag leaves. Besides flag leaf blade width contributed positively in producing lengthier peduncles and panicles.

Association of days to 50% flowering and days to maturity with other yield components revealed that plants with higher number of tillers flowered and matured late as predicted, because more vegetative growth delays onset of reproductive phase hence maturity. Fodder yield per plant had positive correlation with most of the component traits including number of tillers, flag leaf size and plant height as expected; similarly, harvest index revealed consistent negative association with fodder yield and most of the yield component traits.

All three biochemical parameters though were interrelated negatively with each other, total carbohydrate content showed consistent association with grain yield and the major yield components, *viz*., number of basal tillers per plant, flag leaf size, number of productive tillers per plant and 1000 seed weight.

Similar findings of positive significant correlation of grain yield with plant height, 1000 seed weight and fodder yield per plant both at genotypic and phenotypic levels was reported by Shinde *et al.*(2018) and for negative but non-significant correlation of grain yield with number of basal tillers per plant, number of productive tillers per plant, panicle length and crude protein content was reported by Suryanarayana and Sekhar (2018) in little millet.

Correlation among different desirable traits is further precisely divided into direct and indirect effects through path analysis which helps in strategizing breeding procedure for simultaneous selection aiming to improvement in any/every crop.

Table 3. Direct and indirect effect of different characters on grain yield in little millet

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Genotypic correlation with GY/P
1	**-0.024**	-0.254	-0.029	-0.043	0.001	0.151	0.034	-0.030	0.304	0.014	0.068	-0.086	-0.003	-0.001	0.020	0.12
2	0.007	**0.923**	-0.001	0.065	0.001	-0.050	-0.013	0.062	-0.992	-0.021	0.155	-0.348	-0.001	-0.001	-0.006	-0.22
3	-0.007	0.013	**-0.093**	0.093	0.003	0.040	-0.019	0.102	-0.001	0.008	0.206	-0.359	-0.004	-0.001	-0.015	-0.04
4	0.005	0.298	-0.043	**0.202**	-0.001	-0.035	-0.037	0.098	-0.301	-0.005	0.413	-0.448	-0.005	-0.001	-0.016	-0.13
5	0.001	-0.025	0.005	0.002	**-0.054**	-0.005	0.021	-0.045	0.045	-0.008	-0.153	-0.055	0.007	0.001	-0.003	-0.27
6	-0.023	-0.300	-0.024	-0.045	0.002	**0.155**	0.034	-0.038	0.339	0.016	0.054	-0.046	-0.006	-0.001	0.019	0.14
7	0.008	0.125	-0.018	0.075	0.012	-0.053	**-0.098**	0.089	-0.140	0.006	0.128	-0.092	0.002	-0.001	0.005	0.04
8	0.003	0.218	-0.036	0.076	0.009	-0.023	-0.033	**0.261**	-0.226	0.011	0.608	-0.479	-0.008	-0.001	-0.020	0.36*
9	0.007	0.912	0.001	0.061	0.002	-0.052	-0.014	0.059	**-1.005**	-0.022	0.151	-0.327	-0.002	0.001	-0.005	-0.24
10	-0.009	-0.498	-0.019	-0.206	0.011	0.061	-0.014	0.071	0.549	**0.040**	0.322	-0.126	-0.003	0.001	-0.021	0.34*
11	-0.002	0.139	-0.019	0.082	0.008	0.008	-0.012	0.155	-0.148	0.013	**1.024**	-0.804	-0.009	0.001	-0.005	0.43**
12	0.002	-0.299	0.031	-0.084	0.003	-0.007	0.008	-0.116	0.306	-0.005	-0.767	**1.074**	0.003	0.001	0.020	0.17
13	-0.002	0.034	-0.011	0.027	0.011	0.024	0.005	0.056	-0.045	0.003	0.252	-0.084	**-0.036**	0.001	0.002	0.24
14	0.006	-0.129	0.020	-0.042	-0.004	-0.026	0.027	-0.050	0.107	-0.005	-0.107	0.200	-0.002	**0.004**	0.011	0.01
15	0.004	0.046	-0.012	0.027	-0.001	-0.024	-0.004	0.044	-0.041	0.007	0.040	-0.182	0.001	0.001	**-0.120**	-0.22

*, ** significant at 5% and 1% level of significance respectively. **Residual effect = 0.1636**

1. Number of basal tillers per plant
2. Days to 50% flowering
3. Flag leaf blade length)
4. Flag leaf blade width
5. Peduncle length
6. Number of productive tillers per plant
7. Panicle length
8. Plant height
9. Days to maturity
10. 1000 seed weight
11. Fodder yield per plant
12. Harvest index
13. Total carbohydrate
14. Crude protein
15. Total phenol

GY/P = Grain yield per plant

If coefficient between causal factors and direct effect are nearly equal, it reveals true and perfect relationship between the component traits hence direct selection for those traits will be effective. Thus, path analysis provides the information about yield components and their relative importance. Since the magnitude of genotypic correlation coefficients was desirable and was found higher than phenotypic correlation coefficients for most of the character pairs, only genotypic correlation coefficients were considered for path analysis.

The direct and indirect contribution of each component character towards grain yield per plant in little millet is presented in **Table 3**.

Harvest index and fodder yield per plant were positively associated with grain yield per plant. Both the traits, recorded maximum direct effect (1.074 and 1.024) on grain yield per plant. Similar findings were reported by Anuradha *et al.*(2020).

Days to 50% flowering (0.923), plant height (0.261), flag leaf blade width (0.202), number of productive tillers per plant (0.155), 1000 grain weight (0.040) and crude protein content (0.004) also had positive direct effect on grain yield per plant. This result is in accordance with Nagar *et al*.(2014) in little millet. On the other hand, days to maturity (-1.005), total phenol content (-0.120), panicle length (-0.098), flag leaf blade length (-0.093), peduncle length (-0.054), total carbohydrate content (-0.036) and number of basal tillers per plant (-0.024) had negative direct effect on grain yield per plant. Similar results were provided by Madhavilatha *et al*.(2020) in little millet.

Positive and negative indirect effects on grain yield were observed *via* 225-character combinations among 15 component traits through path analysis. It was observed that 11 out of 15 characters contributed positively *via* fodder yield per plant, followed by number of basal tillers per plant and peduncle length. On the other hand, harvest index, followed by total carbohydrate content and flag leaf blade length were the three characters through which maximum negative indirect effects on grain yield were contributed by the 15 component characters.

From the above results, thus it became clear that direct selection based on fodder yield per plant, plant height and 1000 seed weight may help in augmenting grain yield in the experimental material, whereas harvest index and fodder yield per plant are the most important characters for indirect selection.

It can be concluded that fodder yield per plant is the most important component character in little millet because of its high significant positive association with grain yield, its high direct effect on grain yield and being the most used path by the other component traits contributing positively towards grain yield.

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