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Full Research Article

Genetic Variability and Association Analysis for Grain Yield and Nutritional Quality in Foxtail Millet

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Abstract

Foxtail millet is one of the climate resilient crops having great capabilities to sustain agriculture production in near future. Forty four genotypes of foxtail millet were evaluated to study the genetic variability, correlation and path coefficients. The Estimates of genotypic and phenotypic coefficients of variation were high for number of productive tillers plant^{-1}, number of panicles plant^{-1}, grain yield plant^{-1}, straw yield plant^{-1} and iron content. All the traits except plant height had the maximum heritability. High genetic advance as per cent of mean coupled with high estimates of broad sense heritability (h^2_b) (>60%) indicated that, the variation observed for most of the traits were heritable and selection would be effective for improvement of these traits. Grain yield plant^{-1} (g) was highly significant and positively correlated with number of productive tillers plant^{-1}, panicle length, number of panicles plant^{-1}, 1000-grain weight, straw yield plant^{-1} and protein content. The selection in positive direction for these traits with grain yield plant^{-1} (g) can be practiced for genetic enhancement of grain yield. Path coefficient analysis revealed that 1000-grain weight had the highest positive direct effects on grain yield plant^{-1}. The indirect effect of number of panicles, panicle length (cm), number of productive tillers and straw yield through 1000-grain weight was positive and moderate to high indicating the direct selection for 1000-grain weight in foxtail millet will lead to simultaneous indirect selection of these traits for increased grain yield plant^{-1}.

1. Introduction

Research on climate change is the priority area world over, to formulate the strategies for combating its negative effects on agriculture and food security. One of the strategies is to grow climate resilient crops to sustain over all food availability. Millet crops are regarded as climate saviour crops which can be grown on very limited resources. Foxtail millet is very important millet which is widely grown in temperate, subtropical, tropical Asia and in parts of southern Europe. According to Vavilov (1926), the principal centre of diversity for foxtail millet is East Asia, including China and Japan. It is an important grain crop in China, India and Japan and they are the major foxtail millet growing countries in the world. In India, the cultivation of foxtail millet is confined to Andhra Pradesh, Karnataka and Tamil Nadu and some parts of Maharashtra. It is well recognized as a short duration, rainy season crop. The foxtail millet grain is (100 g^{-1}) rich in protein (11.2 g) and iron (2.8 mg) as compared to rice (7.9 g protein and 1.8 mg Fe) and rich in fat 4.0 g 100 g^{-1} which is superior to rice and wheat. The grain is good source of β-carotene, which is the precursor of Vitamin A (Murugan and Nirmalakumari, 2006). It has very diversified uses and health benefits. Foxtail millet has low glycemic index (GI), used for preparation of low GI food products (biscuits and sweets) which have great value for people suffering from diabetes (Thathola et al., 2010; Anju and Sarita, 2010).

In view of the several merits, this crop deserves increased attention in research. But it has received little research attention in the past years and continued to be a neglected and underutilized crop (Upadhyaya et al., 2009). The potentiality of foxtail millet is not yet exploited properly in India (Channappagaudar et al., 2008). Genetic variability studies provide basic information regarding the genetic properties of the population based on which breeding methods are formulated for further improvement of the crop.

The knowledge of relationship among the different traits is of paramount importance for any crop improvement programme. The association between any two variables can be worked out by correlation studies. The phenotypic, genetic and environmental correlations between two traits are estimated for planning breeding strategy. However, among these the genetic correlation is the most important, which may be the result of genetic linkage or pleiotropic effects (Falconer and Mackay, 1996). The correlations can be very high due to the effects of other traits and can result in errors in selection strategy. In this situation, path analysis can be used to reveal the causes involved in inter-trait relations, partitioning the correlation in to direct and indirect effects of independent variables on a dependent variable. The aim of this study was to assess the variability for different traits and estimate the direct and indirect effects of some agronomic and biochemical traits on grain yield through path analysis.

2. Materials and Methods

Forty-four genotypes of foxtail millet were collected from the Unit of All India Coordinated Research Project (AICRP) on small millet, National Agriculture Research Project (NARP), Shenda Park, Kolhapur and grown in randomized block design with three replications during *kharif* 2009 and *kharif* 2010 at Post Graduate Farm, Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri, Maharashtra, India. Each genotype was sown in 3 rows of 2 m length with spacing of 30×10 cm^2. Ten competitive plants were randomly selected in each genotype in each replication to record observation on days to panicle initiation, days to 50% flowering, days to maturity, number of productive tillers plant^{-1}, plant height, number of panicles plant^{-1}, panicle length, 1000 grain weight, grain yield plant^{-1}, straw yield plant^{-1}, protein content and iron content. The means for the two seasons (*kharif* season of 2009 and 2010) werepooled and the pooled means of each replication were used for the analysis. The genotypic and phenotypic coefficient of variation (GCV and PCV) were computed as suggested by Burton, 1952, broad sense heritability (Lush, 1948) and genetic advance (Johnson et al., 1955) were also computed. Besides, genotypic correlations along with the path coefficients were calculated as suggested by Dewey and Lu (1959).

3. Results and Discussion

The analysis of variance revealed highly significant differences among the genotypes, for twelve characters studied. Mean sum of squares for genotypes, environments and genotype×environment were significant. Genetic parameters of variation for yield and its components are given in (Table 1). High PCV was observed for number of productive tillers plant^{-1}, number of panicles plant^{-1}, grain yield plant^{-1}, straw yield plant^{-1} and iron content while, days to panicle initiations, plant height, panicle length, 1000 grain weight and protein content had moderate PCV. The same trend was observed for GCV estimates in all traits except days to panicle initiation, days to 50% flowering and plant height which recorded low GCV values. All the traits exhibited narrow differences between PCV and GCV. High heritability was observed for all the traits except plant height, which had low heritability. The estimate of genetic advance as % of mean was high for all the characters except for days to maturity and plant height. The grain yield and its components like days to panicle initiation, days to 50% flowering, number of productive tillers, panicle length, number of panicles plant^{-1}, 1000 grain weight, grain yield plant^{-1}, straw yield plant^{-1}, protein content and iron content showed high genetic advance as % of mean coupled with high heritability indicating that, the variations are attributable to high level of heritable variation and selection would be effective for improvement of these traits. High heritability coupled with high genetic advance as % of mean were also reported in the earlier studies in foxtail millet for days to panicle initiation (Cill and Randhawa, 1975), days to 50% flowering (Nirmalakumari et al., 2008), number of productive tillers plant^{-1} (Islam et al., 1990), panicle length, 1000 grain weight and grain yield (Nirmalakumari and Vetriventhan, 2010; Nirmalakumari et al., 2008) and iron content (Phillip and Maloo, 1996). Days to maturity exhibited high heritability and low genetic advance. Similar results were reported by Cill and Randhawa, 1975.

The grain yield plant^{-1} was significantly and positively correlated with number of productive tillers plant^{-1}, panicle length, number of panicles plant^{-1}, 1000 seed weight, straw yield plant^{-1} and protein content (Table 2). These traits also showed high heritability coupled with high genetic advance as % of mean; hence selection for these traits will improve the grain yield in foxtail millet. In earlier reports, positive correlation was reported for number of productive tillers plant^{-1} (Nirmalakumari and Vetriventhan, 2010; Rathod et al., 1996) panicle length (Nirmalakumari and Vetriventhan, 2010; Murugan and Nirmalakumari, 2006), straw yield plant^{-1} (Murugan and Nirmalakumari, 2006; Santhakumar, 1999;) reported in foxtail millet. Days to panicle initiation, days to 50% flowering, days to maturity, were significant and negatively correlated with grain yield plant^{-1}. Similar reports were found for days to 50% flowering (Upadhyaya et al., 2009; Cill and Randhawa, 1975) and days to maturity (Reddy and Jhansilakshmi, 1991).

The direct effect of 1000 grain weight on grain yield plant^{-1} (g) was positive which indicated the true relationship of this trait and a direct selection through this trait will be effective (Table 3 and Figure 1). The indirect effect of no. of panicles, panicle length (cm), no. of productive tillers and straw yield through 1000 grain weight was positive and moderate to high. It can be inferred that, the direct selection of 1000 grain weight

Table 1: Variability parameters for various characters in foxtail millet across environments

Sl. No.	Characters	Range	General mean	PCV	GCV	Heritability h^2 (bs)	Genetic advance	Genetic advance as % mean
1.	Days to panicle initiations	43.33-67.83	48.16	11.83	11.44	93.50	14.06	29.20
2.	Days to 50% flowering	56.83-81.00	60.70	8.71	8.48	94.70	13.22	21.78
3.	Days to maturity	90.00-123.67	97.77	6.39	6.18	93.50	15.44	15.79
4.	No. of productive tillers plant^{-1}	0.90-3.73	2.48	30.46	27.85	83.60	1.66	67.25
5.	Plant height (cm)	110.73- 185.18	137.21	14.25	10.34	52.70	27.21	19.83
6.	Panicle length (cm)	7.82-22.42	17.84	15.87	14.34	81.70	6.10	34.22
7.	No. of panicles plant^{-1}	1.90-4.73	3.48	21.71	19.85	83.60	1.66	47.93
8.	1000 grain weight (g)	1.07-3.44	2.82	16.96	16.17	90.90	1.14	40.71
9.	Grain yield plant^{-1} (g)	6.70- 21.68	16.01	22.66	19.75	76.00	7.27	45.44
10.	Straw yield plant^{-1} (g)	13.49-47.19	27.14	27.58	26.04	89.10	17.61	64.92
11.	Protein content (%)	7.08-13.75	10.35	13.35	12.81	92.10	3.36	32.46
12.	Iron content (%)	0.03-0.10	0.05	23.68	23.61	99.30	0.03	62.13

Table 2: Genotypic correlation coefficients between 12 characters in foxtail millet

Sl. No.	Char-acters	DPI	DF	DM	NPTP	PH (cm)	PL (cm)	NPP	GW (g)	SYP (g)	PC (%)	IC (%)	GYP (g)
1.	DPI	1.000	0.968^{**}	0.688^{**}	0.128	0.127	-0.475^{**}	0.128	-0.240	-0.333^{*}	-0.182	-0.332^{*}	-0.475^{**}
2.	DF		1.000	0.754^{**}	0.163	0.038	-0.564^{**}	0.163	-0.181	-0.352^{*}	-0.150	-0.314^{*}	-0.503^{**}
3.	DM			1.000	0.458^{**}	-0.324^{*}	-0.785^{**}	0.458^{**}	-0.113	-0.238	0.029	-0.261	-0.510^{**}
4.	NPTP				1.000	-0.476^{**}	-0.468^{**}	1.000^{**}	0.368^{*}	0.477^{**}	0.202	-0.240	0.320^{*}
5.	PH (cm)					1.000	0.535^{**}	-0.476^{**}	0.153	0.112	-0.141	0.103	0.110
6.	PL (cm)						1.000	-0.468^{**}	0.206	0.221	0.074	0.155	0.512^{**}
7.	NPP							1.000	0.368^{*}	0.477^{**}	0.202	-0.240	0.320^{*}
8.	GW								1.000	0.456^{**}	0.282	-0.121	0.706^{**}
9.	SYP (g)									1.000	0.270	-0.104	0.610^{**}
10.	PC (%)										1.000	-0.130	0.319^{*}
11.	IC (%)											1.00	0.035

DPI: Days to panicle initiation; DF: Days to 50 % flowering; DM: Days to maturity; NPTP: No. of productive tillers plant^{-1}; PH: Plant height; PL: Panicle length; NPP: No. of panicles plant^{-1}; GW: 1000 grain wt.; SYP: Straw yield plant^{-1}; PC: Protein content; IC: Iron content; GYP: Grain yield plant^{-1}; $^{*}p<0.05$ and $^{**}p<0.01$

in foxtail millet lead to simultaneous indirect selection of no. of panicles, panicle length (cm), number of productive tillers and straw yield for increased grain yield plant^{-1}. Hawlader and Hamid (1988) also reported the highest direct effect of 1000 grain weight on grain yield. The residual effect determines how best the causal factors account for the variability of the dependent factors, i.e yield in this case. Its estimate being 0.360, explained about 64% variability in the yield. This indicated that, the reasonable proportion of the variability was captured in foxtail millet germplasm. The residual variance was low which indicated the importance of the characters taken in this study and accounted more variation for grain yield.

Table 3: Direct and indirect effects of 12 quantitative traits on grain yield in foxtail millet

Sl. No.	Characters	DPI	DF	DM	NPTP	PH (cm)	PL (cm)	NPP	GW (g)	SYP (g)	PC (%)	IC (%)
1.	DPI	0.490	0.474	0.337	0.063	0.062	-0.233	0.063	-0.118	-0.163	-0.089	-0.163
2.	DF	-0.339	-0.350	-0.264	-0.057	-0.013	0.198	-0.057	0.063	0.123	0.053	0.110
3.	DM	-0.358	-0.392	-0.520	-0.238	0.169	0.408	-0.238	0.059	0.124	-0.015	0.135
4	NPTP	0.057	0.073	0.204	0.446	-0.213	-0.209	0.446	0.164	0.213	0.090	-0.107
5.	PH (cm)	-0.014	-0.004	0.037	0.054	-0.114	-0.061	0.054	-0.017	-0.013	0.016	-0.012
6.	PL (cm)	-0.134	-0.159	-0.222	-0.132	0.151	0.283	-0.132	0.058	0.062	0.021	0.044
7.	NPP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8.	GW (g)	-0.110	-0.083	-0.052	0.169	0.070	0.095	0.169	0.460	0.210	0.130	-0.056
9.	SYP (g)	-0.011	-0.012	-0.008	0.016	0.004	0.007	0.016	0.015	0.033	0.009	-0.003
10.	PC (%)	-0.022	-0.018	0.004	0.024	-0.017	0.009	0.024	0.033	0.032	0.118	-0.015
11.	IC (%)	-0.034	-0.032	-0.027	-0.025	0.011	0.016	-0.025	-0.012	-0.011	-0.013	0.102
12.	Grain yield plant^{-1} (g)	-0.475	-0.503	-0.510	0.320	0.110	0.512	0.320	0.706	0.610	0.319	0.035

DPI: Days to panicle initiation; DF: Days to 50 % flowering; DM: Days to maturity; NPTP: No. of productive tillers plant^{-1}; PH: Plant height (cm); PL: Panicle length; NPP: No. of panicles plant^{-1}; GW: 1000 grain weight.; SYP: Straw yield plant^{-1}; PC: Protein content; IC: Iron content

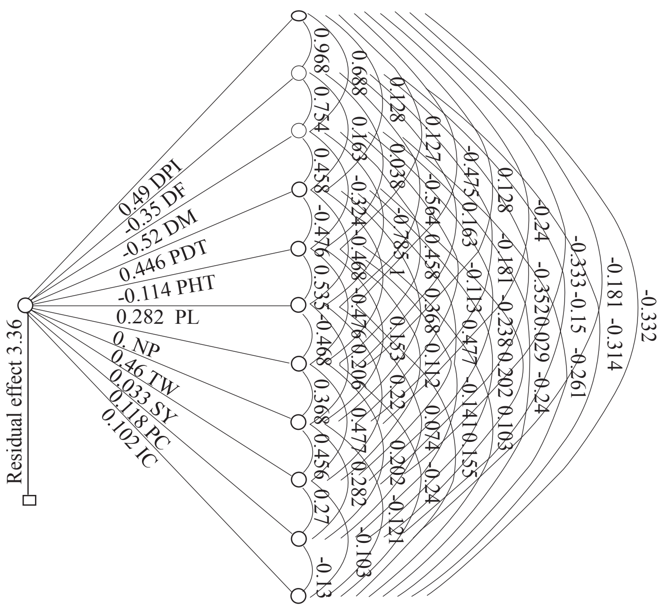

Figure 1: A path diagram showing relationship between Grain yield plant^{-1} and some growth parameters across environments; DPI: Days to panicle initiation; DF: Days to 50% flowering; DM: Days to maturity; PDT: Productive tillers plant^{-1}; PHT: Plant height; PL: Panicle length; NP: Number of panicles plant^{-1}; TW: 1000 grain weight, SY: Straw yield plant^{-1}; PC: Protein content; IC: Iron content

4. Conclusion

The direct and indirect effects found in this study would help to understand the real cause of the correlations between the explanatory variables and the grain iron and protein levels. This would help in planning of breeding strategy for developing bio-fortified varieties. Direct selection for 1000-grain weight in foxtail millet will be helpful for the simultaneous indirect selection of number of panicles, panicle length (cm), number of productive tillers and straw yield for increased grain yield in foxtail millet.

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