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Research Article

Genetic variability, correlation and path coefficient studies in sorghum [*Sorghum bicolor* (L.) Moench] mutants

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Abstract
The present study was undertaken to assess genetic variability present in the mutant derived from Chincholli-2 and JP 1-5 landraces in M_4 generation and estimate the correlation and path coefficients among yield and attributing traits. The present study revealed wide variation for morphological and yield contributing traits. Among the genetic parameters studied, high phenotypic and genotypic coefficient of variation (PCV, GCV), heritability and genetic advance was observed for panicle length, panicle weight, panicle width, seed weight and grain yield. Significant positive correlations were observed between grain yield and number of leaves, plant height, stems girth, panicle length, panicle area indicating the role and importance of these traits in the development of high yielding varieties. The path analysis revealed positive and direct effect of days to maturity, number of leaves, plant height, stem girth, panicle length, panicle weight and panicle width on grain yield per plant. This study would help in developing high yielding mutants for deep black soils of northern Karnataka under rainfed conditions.

Key words
Sorghum, Correlation, Path coefficient, Mutation breeding

Introduction

Sorghum is an important food crop in the world after corn, wheat, rice and barely. It is a multipurpose crop that can be used as a source of food, feed and fuel. It is primarily an important food source in the semi-arid regions of Africa and Asia, but also has wide utilization as livestock feed and biofuel. It has wide adaptability and requires fewer inputs and drought tolerance compared to other crops. India is a major sorghum growing country in the world covering 4.9 m.ha with production of 4.7 m. tonnes. In India, it is grown as a dual purpose crop for serving both grain and fodder requirements of the farming community.

Rabi sorghum improvement was initiated in the early seventies through the selections from land races and pure lines. The traditional and widely preferred land races were ineffective as donor of favorable gene complex in traditional breeding. To enhance the breeding program and to create new genetic variation, mutation breeding has been utilized. Mutation breeding has played an important role in crop improvement (Larik and Jamro, 1993) with an objective of increasing the genetic variability effective for selection. It has been found that irradiation of seeds with physical or chemical mutagens would lead to increase in mutation frequency, promote favorable gene modifications and creates wide genetic variability (Mike, 1996). In order to utilize this variation for genetic improvement, knowledge of association between morphological and yield contributing traits are required, which will help in evaluating the contribution of these traits. Often selections made based on phenotypic performance may not lead to expected genetic advance, due to the presence of environmental factors and undesirable association between component traits. Hence, the knowledge of correlation between complex quantitative traits and genetic variability parameters will help in designing efficient selection strategies for identifying desirable mutants. The path coefficient analysis helps in partitioning correlation coefficient into direct and indirect effects across various traits. This would also help in assessing the casual effect relationships and effective selection (Khandelwala *et al.*, 2015). In the present investigation, two sorghum varieties *i.e.*, Chincholli local and JP-1-5 were selected for improving the yield levels using mutation breeding techniques.

Materials and Methods

Two landraces, *viz.*, Chincholli local and JP-1-5 were earlier subjected to physical (gamma rays @ 300Gy) and chemical mutagens (Ethyl Methane Sulphonate @ 0.1%). M_1 and subsequent generations were grown as plant to row progenies at Agricultural Research Station (ARS), Kalaburagi. In each generation, selections were performed for grain yield and charcoal rot tolerance. In M_4 generation (2015- 16), a total of 148 mutant lines consisting of 61 mutants of chincholli-2 and 87 mutants of JP-1-5 were selected for planting. They were sown in Augmented design, (Federer, 1977) in 4 blocks of 4m length with inter row spacing of 45 cm and intra row spacing of 15 cm. Each block contained 37 mutants and eight checks *viz.*, DJ 6514, IS 2312, M 35-1, DSV-4, E-36-1, SPV-86, JP-1-5, Chincholli replicated in four blocks. The observations were recorded on five randomly selected mutant plants in each entry for eleven traits (days to 50 per cent flowering, days to maturity, plant height (cm), panicle length (cm), panicle neck length (cm), number of leaves, stem girth (cm), panicle width (cm), panicle weight (g), 100-seed weight (g) and grain yield per plant (g)). Analysis of variance was carried out as per the Panse and Sukhatme (1978). Genotypic and phenotypic coefficient of variability, heritability and genetic advance as per the standard method suggested by Burton (1952). The direct and indirect effects were studied through path analysis as per the procedure of Dewey and Lu, 1959. The statistical analysis of the phenotypic data on individual trait was carried out based on mean values of each mutant using INDOSTAT package (version 8.5).

Results and Discussions

The present study was carried out to estimate the genetic variability and correlations among yield and yield contributing traits. A landrace, Chincholli-2 was initially irradiated with gamma rays at 300 Gy and selfed progenies were forwarded from M_1 to M_4 generations. The variability found was enormous among the yield contributing traits in the M_2 and subsequent generations and selections were made for grain yield traits and charcoal rot tolerance. Among the M_4 families selected, significant amount of variability was observed for most of morphological and yield characters studied *viz*., days to 50% flowering, days to maturity, plant height, stem girth, panicle length, panicle weight, panicle width, 100 seed weight and grain yield per plant. Range, mean, PCV, GCV, heritability estimates in broad sense and genetic advance as percent mean for these characters is presented in Table 1. Plant height, panicle neck length, panicle weight and grain yield per plant have shown higher range values. The presence of such wide range of variation of the traits indicated that the presence of large amount of genetic variation among the mutants.

High values of PCV and GCV were observed for the traits like panicle weight, panicle width and seed yield per plant. Moderate values were observed for plant height, panicle length, stem girth and 100 seed weight. In another case, low values of GCV were also observed for days to 50 per cent flowering, days to maturity, number of leaves and panicle neck length which indicated that improvement of this traits through selection is less effective due to lack of genetic variability among the. Yaqoob *et al.* (2015) observed high PCV and GCV for plant height, leaf area index, stalk yield per plant and grain yield per plant, moderate for number of leaves and 100 grain weight and low for days to 50 percent flowering and maturity. In general, GCV value was generally smaller than their corresponding PCV values for all the traits considered indicating the contribution of environmental variance to the total phenotypic variance of the trait. Narrow difference between PCV and GCV was observed for days to 50 per cent flowering and maturity, plant height, panicle length, stem girth, panicle width, panicle weight, grain yield per plant and 100-seed weight. This showed that these characters were less affected by environmental fluctuations and offer better scope for selection. On the other hand, number of leaves and panicle neck length showed wide difference for PCV and GCV values, indicating the role of environment.

In the present study, high heritability was observed for days to 50 per cent flowering, days to maturity, plant height, panicle neck length, stem girth, panicle width, panicle weight, grain yield per plant and seed weight. Similarly, Anand and Kajjidoni (2014) also assessed genetic variability for grain size and productivity in kharif sorghum and reported high heritability values of more than 90 % for plant height and grain yield per plant in the sorghum mutant progenies. High heritability along with high genetic advance as per cent mean was observed for plant height, stem girth, panicle weight, panicle width, 100 seed weight, panicle length and grain yield per plant. These characters were found to be under additive gene action thus enabling for selection. Sushil (2014) evaluated 102 land races of forage sorghum and observed high heritability accompanied with high genetic advance for days to flowering, plant height, number of leaves per plant and leaf length. For the days to 50 per cent flowering, days to maturity and number of leaves heritability estimates were moderate to high and genetic advance as per cent mean was low, which is in accordance with Tariq *et al.*, 2012. In addition, dry matter yield, fresh weight per plant and dry weight per plant showed high heritability except for number leaves per plant (moderate heritability). This could be due presence of non additive nature and influence of environment. Hence, selection for the trait would not be rewarding (Tariq *et al.*, 2012).

The grain yield had significantly positive correlation with number of leaves, plant height, stem girth, panicle length, panicle weight and panicle width (Table 2). Deepalakshmi and Ganesamurthy (2007) evaluated 16 genotypes of white grain sorghum, where they found seed yield was positively and significantly correlated with days to maturity, number of leaves per plant and ear head weight Similarly plant height, panicle length, panicle width, and stem girth had highly significant positive correlation with grain yield per plant which is in accordance with findings of Girish *et al.* (2016) evaluated 25 lines of sorghum during rabi season 2015 and reported seed yield per plot showed significant positive correlation with plant height, ear head length, 100 seed weight, fodder yield and lodging percentage. Therefore, the positive association of grain yield with these traits suggested that the possibility of simultaneous improvement of grain yield through indirect selection of these positively correlated traits.

In the present study, out of 11 characters, days to maturity, number of leaves, plant height, stems girth, panicle length, panicle weight and panicle width were contributed positive and direct effect towards grain yield (Table 3). Among these, panicle weight has high positive direct effect whereas; the direct effects of other characters were negligible. Panicle weight exerted maximum direct effect on grain yield per plant followed by days to maturity, plant height, stem girth, panicle width, number of leaves and panicle length. It indicated that if other factors are held constant, an increase in these characters individually will reflect in an increased yield. Many other workers have also considered panicle weight, days to maturity, plant height, stem girth, panicle length, and panicle width to be most important yield components having direct effect. Amare *et al.* (2015) investigated in 16 sorghum varieties, path analysis indicated plant height, panicle weight and harvest index showed high positive phenotypic direct effect on yield whereas panicle yield showed negligible positive phenotypic direct effect with considerable indirect via panicle weight. While other characters like days to 50% flowering, panicle neck length and seed weight had negative direct effects on grain yield. These results were in conformity with the observations made by Mahendrakumar *et al.* (2014) in rice mutants.

The indirect effects of number of leaves, plant height and stem girth were positive and minimal *via* panicle weight on grain yield and the indirect effects of panicle length and panicle width were positive and moderate *via* panicle weight. The direct effects of days to 50 per cent flowering and 100 seed weight were negative and contribute positively towards yield. This could be due to positive indirect effects of both characters towards yield through other characters. The indirect effects of days to 50 per cent flowering, days to maturity, number of leaves, plant height, stem girth, panicle neck length, panicle length, panicle weight, panicle width and 100 seed weight *via* other characters were negligible. Shinde *et al*. (2014) studied the correlation among yield and its attributing traits in 120 F_6 derived lines. The path analysis of different characters in this study revealed positive and direct effects of panicle breadth and seed weight on grain yield, while number of grains per panicle are indirectly and positively associated with grain yield.

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Table 1. Mean, range and genetic parameters for yield and yield attributing traits in sorghum mutants (M_4)

Character	Range			Co-efficient of variation		Heritability (%) broad sense	Expected Genetic advance @ 5%	Genetic advance as % of mean
	Min.	Max.	Mean	GCV	PCV			
DFF	55.00	72.00	68	2.60	2.94	78.63	3.23	4.76
DM	102.00	117.00	112	2.52	2.69	87.33	5.43	4.85
NL	6.50	13.33	11	7.02	11.28	38.77	0.97	9.01
PH	75.00	221.00	160	12.89	16.11	64.00	34.34	21.25
SG	0.95	2.53	1.51	16.98	19.00	79.89	48.60	31.26
PNL	4.00	19.67	9.30	7.63	24.23	9.92	0.44	4.95
PL	7.00	22	12.34	14.74	19.55	56.83	2.80	22.89
PW	8.67	69.33	36.74	26.87	33.41	64.69	16.33	44.52
PWT	1.17	5.70	3.63	20.93	22.71	84.97	1.44	39.75
100SW	1.85	4.07	2.94	11.69	13.02	80.71	64.36	21.64
GYPP	4.50	41.26	19.33	27.55	34.82	62.61	8.72	44.91

DFF= Days to 50% flowering DM = Days to maturity NL= Number of leaves (cm) PH= Plant height (cm)
SG= Stem girth (cm) PNL= Panicle neck length (cm) PL= Panicle length (cm) PW = Panicle Weight (gm)
PWT = Panicle width (cm) 100SW= 100 Seed weight (gm) GYPP= Grain yield per plant (gm)

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Table 2. Correlations coefficients for yield and attributing traits in sorghum mutants

Character	DM	NL	PH	SG	PNL	PL	PW	PWT	100SW	r_{gypp}
DFF	0.6490 **	0.0858	0.1141	0.1459	-0.1132	0.1413	0.0122	0.0063	0.0954	0.0276
DM	**1**	0.0911	0.1016	0.1505 *	-0.1675 *	0.2236 **	0.0451	-0.0381	-0.1490 *	0.1095
NL		**1**	0.6093 **	0.4492 **	-0.3958 **	0.2553 **	0.1221	0.4188 **	-0.0616	0.1849*
PH			**1**	0.3408 **	-0.0441	0.4645 **	0.1958 **	0.5500 **	-0.0861	0.2398**
SG				**1**	-0.2859 **	0.0745	0.1776 *	0.3330 **	0.0733	0.2229**
PNL					**1**	0.0942	0.0790	0.0429	-0.1143	-0.0025
PL						**1**	0.2426 **	0.2407 **	-0.3121 **	0.2550**
PW							**1**	0.3192 **	0.0831	0.9090**
PWT								**1**	0.0338	0.3291**
100SW									**1**	0.0498
GYPP										**1**

** = Significant at 1 per cent * = Significant at 5 per cent
DFF= Days to 50% flowering DM = Days to maturity NL= Number of leaves (cm) PH= Plant height (cm)
SG= Stem girth (cm) PNL= Panicle neck length (cm) PL= Panicle length (cm) PW = Panicle Weight (gm)
PWT = Panicle width (cm) 100SW= 100 Seed weight (gm) GYPP= Grain yield per plant (gm)

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Table 3. Phenotypic path analysis of different yield components among sorghum mutants

Characters	DFF	DM	NL	PH	SG	PNL	PL	PW	PWT	100SW	r_{gypp}
DFF	**-0.0518**	0.0547	0.001	0.0036	0.0031	0.0062	0.0007	0.0109	0.0001	-0.0010	0.0276
DM	-0.0336	**0.0842**	0.0011	0.0032	0.0032	0.0092	0.0011	0.0403	-0.0008	0.0015	0.1095
NL	-0.0044	0.0077	**0.0121**	0.019	0.0096	0.0218	0.0013	0.1089	0.0084	0.0006	0.1849*
PH	-0.0059	0.0086	0.0074	**0.0311**	0.0073	0.0024	0.0024	0.1747	0.0111	0.0009	0.2398**
SG	-0.0076	0.0127	0.0054	0.0106	**0.0213**	0.0157	0.0004	0.1584	0.0067	-0.0008	0.2229**
PNL	0.0059	-0.0141	-0.0048	-0.0014	-0.0061	**-0.0550**	0.0005	0.0705	0.0009	0.0012	-0.0025
PL	-0.0073	0.0188	0.0031	0.0145	0.0016	-0.0052	**0.0051**	0.2164	0.0048	0.0032	0.255**
PW	-0.0006	0.0038	0.0015	0.0061	0.0038	-0.0043	0.0012	**0.8920**	0.0064	-0.0009	0.909**
PWT	-0.0003	-0.0032	0.0051	0.0171	0.0071	-0.0024	0.0012	0.2847	**0.0201**	-0.0003	0.3291**
100SW	-0.0049	-0.0126	-0.0007	-0.0027	0.0016	0.0063	-0.0016	0.0741	0.0007	**-0.0103**	0.0498

Phenotypic residual value = 0.399
**** =** Significant at 1 per cent * = Significant at 5 per cent
DFF= Days to 50% flowering DM = Days to maturity NL= Number of leaves (cm) PH= Plant height (cm)
SG= Stem girth (cm) PNL= Panicle neck length (cm) PL= Panicle length (cm) PW = Panicle Weight (gm)
PWT = Panicle width (cm) 100SW= 100 Seed weight (gm) GYPP= Grain yield per plant (gm)
r_{gypp} = correlation value for grain yield per plant