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Research article

Genetic parameters, correlation and path analysis for fodder and dual purpose sorghum [*Sorghum bicolor* (L.) Moench] genotypes

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Abstract

About 60 diverse sorghum genotypes were evaluated to assess the genetic parameters, association among fodder and grain yield component traits and their direct and indirect effects on grain yield. The experiment was conducted in randomized block design at Instructional Farm, Department of Genetics and Plant Breeding, Rajasthan College of Agriculture (MPUAT), Udaipur in collaboration with AICRP on Sorghum. Analysis of variance revealed highly significant differences among the genotypes for all 14 traits studied. In the present investigation range of the magnitudes of all genetic parameters for each trait was classified based on mean and standard deviation (SD) into three categories *viz.*, high (> $\text{mean} + \frac{1}{2}\text{SD}$), medium (in between $\text{mean} \pm \frac{1}{2}\text{SD}$) and low (< $\text{mean} - \frac{1}{2}\text{SD}$). Traits *viz.*, total soluble solids (%), grain yield per plant (g), leaf breadth (cm) and dry fodder yield per plant (g) were the most approachable for selection as they had higher GCV, PCV, genetic gain and moderate to high heritability in a broad sense. Hence, simple selection could be effective for further improvement of these characters. Based on correlation and path analysis, the traits, dry fodder yield per plant, harvest index, green fodder yield per plant, leaf breadth, protein content and plant height might be considered as indirect selection indices for improvement in grain and fodder yields of sorghum.

Keywords: Correlation, GCV, Genetic gain, Heritability, Path analysis, PCV

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] has worldwide economic importance among cereal crops because of its various uses, compatibility for low input cultivation and adjustment to a broad range of ecological situations (Doggett, 1988; Chand *et al*., 2017). Millions of people depend on it as a staple food, besides a good source of fodder for livestock, particularly in the arid and semi-arid regions of Africa and Asia (Bantilan *et al*., 2001; Dalip *et al*., 2022; Kumar *et al*., 2023). Success in sorghum crop improvement leans on genetic variability, heritability and genetic gain present in the base population, based on which the breeders may be able to plan out suitable breeding methods for further crop improvement (Elangovan *et al*., 2013; Seetharam and Ganeshmurthy, 2013). Characters having high heritability could easily be set with simple selection resulting in speedy progress (Mallinath *et al*., 2004). Nevertheless, heritability is also affected by environment so information on heritability only could not help in recognizing characters enforcing selection. Thus, the estimates of both heritability and genetic gain would be extra trustworthy circumstances for selection (Johnson *et al*., 1955). Selection of genotypes based directly on yield may not be very reliable, because yield being quantitative is a complex character that leans on several other components. Thus, a sound knowledge of the association of yield with other traits would be of great help and for this aspect correlation coefficient suggests a reliable measure of association among the characters and assists in distinguishing desirable associations beneficial in breeding from those of the undesirable ones (Falconer, 1981). Due to the mutual cancellation of component traits, the judgment of correlation alone may be ambiguous. Thus, it is necessary to study the path coefficient analysis, which separates the entire correlation coefficient into direct and indirect effects and evaluates the relative value of the causal factor individually (Dewey and Lu, 1959). Therefore, in the present experiment, an attempt was made to assess the genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV),

Table 1. List of 60 sorghum genotypes used in the present experiment

SU 1426	SU 1578	SU 1601	SPV 1572
SU 1429	SU 1579	SU 1603	SPV 1575
SU 1454	SU 1581	SU 1604	SPV 2165
SU 1477	SU 1582	SU 1607	SPV 2185
SU 1519	SU 1583	SU 1608	SPV2293
SU 1528	SU 1584	SU 1610	SPV2307
SU 1529	SU 1590	SU 1611	SPV 2308
SU1548	SU 1592	SU 1612	SPV 2312
SU 1570	SU1593	SU 1615	SPV 2370
SU 1572	SU1594	SU 1625	SPV 2391
SU 1573	SU 1595	SU 1631	SPV 2398
SU 1574	SU 1597	SPV 96	CO FS 29
SU 1575	SU 1598	SPV 245	PC 1080
SU 1576	SU 1599	SPV 1465	CSV 17
SU 1577	SU 1600	SPV 1569	CSV 23

heritability (h^2) and genetic gain (GG) and correlation and path analysis for 14 traits in 60 diverse sorghum genotypes.

Materials and Methods

Plant materials and experimental design: A total of 60 diverse sorghum genotypes were used for the current experiment (Table 1). The experiment was carried out in randomized block design with three replications during *Kharif* 2018 at Instructional Farm, Department of Genetics and Plant Breeding, Rajasthan College of Agriculture (MPUAT), Udaipur, in collaboration with AICRP on Sorghum. Each genotype in each replication was dibbled at a spacing of 45 x 15 cm from row to row and plant to plant, respectively.

***Observations*:** Observations were taken for 14 dual-purpose attributing traits. Observations on 12 traits *viz.*, plant height (cm), stem girth (mm), number of leaves per plant, leaf length (cm), leaf breadth (cm), total soluble solids (%), green fodder yield per plant (g), grain yield per plant (g), dry fodder yield per plant (g), test weight (g), harvest index (g) and protein content (%) were recorded on ten randomly chosen plants in each replication for each entry. Observations on days to 50% flowering and days to maturity were observed based on the total population in each plot. Protein content (%) in grains was carried out by adopting the micro kjeldahl's method as suggested by Linder (1944).

***Statistical analysis*:** It was carried out according to Panse and Sukhatme (1985) for analysis of variance; Burton (1952) for calculation of GCV and PCV; Johnson *et al.* (1955) for heritability and genetic advance; Al-Jibouri *et al.* (1958) for correlation coefficient; Wright (1921) and Dewey and Lu (1959) for path analysis. In the present investigation range of the magnitudes of all genetic parameters for each trait was classified based on mean and standard deviation (SD) in three categories *viz.*, high ($>\text{mean}+\frac{1}{2}\text{SD}$), medium (in between $\text{mean}\pm\frac{1}{2}\text{SD}$) and low ($<\text{mean}-\frac{1}{2}\text{SD}$) (Diwakar *et al.*, 2016).

Results and Discussion

Analysis of variance revealed highly significant differences among all the genotypes for all the traits under study, indicating substantial variability (Table 2).

Genetic Parameters: In general, estimates of phenotypic coefficients of variation (PCV) were slightly greater than their corresponding genotypic coefficient of variation (GCV), indicating the role of the environment in the expression of characters (Table 3). High GCV coupled with high PCV (> 27.05 and 29.00%) were observed for the characters *viz.*, total soluble solids, grain yield per plant, leaf breadth, green fodder per plant and dry fodder yield per plant, designating that simple phenotypic selection might help to improve these traits. According to Burton (1952), GCV in conjunction with heritability, gives a better roadmap of the extent of advance to be expected by selection. High heritability in the broad sense for a particular trait denotes the usefulness of selection based on phenotypic performance. The environmental effects might least influence the trait but do not essentially indicate a high genetic gain for a particular character since broad-sense heritability is based on total genetic variance, which comprises additive, dominant and epistatic variances. The genetic gain would be low if heritability is due to dominance and epitasis gene effects and high genetic gain would be expected when heritability is due to additives gene effects (Panse, 1957). Therefore, high heritability in conjunction with high genetic gain is generally extra useful in expecting the gain under selection. High heritability accompanied by high genetic gain (>89.49 and 52.11%) was observed for total soluble solids, grain yield per plant and leaf breadth, indicating these traits were chiefly under the control of additive gene action, making these traits respond better to selection. Moreover, moderate heritability along with high genetic gain and GCV was recorded for dry fodder yield per plant, representing an influence of environment, but the prevalence of additive gene action, hence these traits might be amenable for selection. Low to moderate heritability along low genetic gain was observed for days to 50% flowering, days to maturity, number of leaves per plant and leaf length, denoting that the presence of non-additive gene action and hence selection of these traits would not be helpful. These findings related to

Table 2. Mean sum of squares for different characters

Characters	Replication [2]	Genotype [59]	Error [118]
Days to 50% flowering	6.51	53.24**	5.40
Days to maturity	5.27	201.44**	9.55
Plant height (cm)	350.73	10349.07**	270.35
Stem girth (mm)	0.79	17.45**	1.28
Number of leaves per plant	1.19	8.64**	0.45
Leaf length (cm)	25.06	638.35**	59.85
Leaf breadth (cm)	0.81	11.20**	0.35
Total soluble solids (%)	3.54	57.31**	1.49
Green fodder yield per plant (g)	98.41	6761.05**	558.99
Grain yield per plant (g)	4.37	853.52**	30.93
Dry fodder per plant (g)	27.62	2439.09**	146.89
Test weight (g)	4.99	80.46**	1.70
Harvest index (%)	1.66	193.51**	16.68
Protein content (%)	0.07	10.10**	0.10

**($p < 0.01$); [ ] : Degree of freedom

Table 3. Estimates of variability parameters for 14 characters studied in sorghum

Characters	GCV	PCV	h^2	GG
Days to 50% flowering	6.06	7.01	74.71	10.79
Days to maturity	7.64	8.19	87.00	14.68
plant height (cm)	23.41	24.33	92.55	46.38
Stem girth (mm)	20.71	23.04	80.76	38.34
Number of leaves per plant	16.79	18.12	85.83	32.04
Leaf length (cm)	17.88	20.46	76.31	32.17
Leaf breadth (cm)	30.21	31.64	91.17	59.43
Total soluble solids (%)	36.80	38.25	92.57	72.94
Green fodder yield per plant (g)	28.91	32.59	78.72	52.84
Grain yield per plant (g)	36.13	38.12	89.86	70.56
Dry fodder yield per plant (g)	28.19	30.78	83.87	53.18
Test weight (g)	17.92	18.49	93.92	35.77
Harvest index (%)	24.20	27.41	77.94	44.01
Protein content (%)	19.26	19.56	96.97	39.07

genetic parameters were in accordance with the findings of Seetharam and Ganesamurthy (2013), Jain and Patel (2014), Malik *et al.* (2015), Ranjith *et al.* (2017), Sujatha and Pushpavalli (2017), Gebregergs and Mekbib (2020), Toor (2020), Sheetal (2021) and Vinodhini *et al.*(2022).

***Correlation*:** Estimates of correlation coefficients of different plant traits are useful criteria to recognize desirable traits, contributing to the improvement of the dependent variable (yield per plant). Correlation coefficients were worked out at both genotypic (rg) and phenotypic (rp) levels for 14 different characters (Table 4). In general, the magnitudes of genotypic correlation coefficients were higher than their counterparts at phenotypic levels for most of the characters under study which was an indication of a strong inherent relationship between various traits studied (Johnson *et al.*, 1955). Grain yield per plant exhibited positive and significant correlation at both genotypic and phenotypic levels with harvest index, dry fodder yield per plant and green fodder yield per plant, indicating that yield could be improved through simultaneous selection for these traits. Grain yield per plant showed a negative and significant correlation at both genotypic and phenotypic levels with days to maturity and only genotypic levels with days to 50% flowering. Regarding intercorrelations among other traits, a positive and significant association at both levels was found between green fodder yield per plant and dry fodder yield and between days to 50% flowering with days to maturity. Both green fodder yield per plant and dry fodder yield per plant showed a positive and significant correlation at both genotypic and phenotypic levels with stem girth and leaf breadth. The association of green fodder yield per plant with leaf length was also positive and significant but at only the genotypic level. Moreover, green fodder yield per plant and dry fodder yield per plant both the traits had negative and significant associations with days to 50% flowering, the correlation between days to maturity and harvest index. Hence, these characters could be taken into consideration as vital fodder yield factors in sorghum. These outcomes of associations were in agreement with outcomes recorded earlier (Pahuja and Dharmveer, 2013; Jain and Patel, 2014; Girish *et al.*, 2016; Khandelwal *et al.*, 2015; Deshmukh *et al.*, 2018; Toor, 2020; Sheetal, 2021; Vinodhini *et al.*, 2022; Patil *et al.*, 2023).

***Path analysis*:** In order to obtain a clear picture of the relative importance of the components on grain yield per plant (g), path coefficients analysis at genotypic and phenotypic levels was carried out using 11 independent characters (Tables 5 and 6). The high estimate of residual effect at genotypic and phenotypic levels (0.7693 and 0.8196) revealed the inadequacy of the traits included for the path analysis and indicated that 23.07 and 18.04% variability at genotypic and phenotypic levels, respectively, of grain yield per plant (g), which these traits could explain under consideration. The study on direct and indirect effects of component characters on grain yield per plant revealed that the highest positive

Table 4. Genotypic and phenotypic correlation coefficients (P\G)

Character	Days to 50% flowering	Days to maturity	plant height (cm)	Stem girth (mm)	Number of leaves per plant	Leaf length (cm)	Leaf breadth (cm)	Total soluble solids (%)	Green fodder yield per plant (g)	Grain yield per plant (g)	Dry fodder per plant (g)	Test weight in (g)	Harvest index (%)	Protein content (%)
Days to 50% flowering	1	0.78**	0.19	-0.24	0.33**	0.05	-0.22	-0.22	-0.33*	-0.32*	-0.39**	-0.15	-0.07	-0.07
Days to maturity	0.67**	1	0.15	-0.32*	0.25	-0.22	-0.45**	-0.29*	-0.38**	-0.36**	-0.46**	-0.19	-0.08	0.03
plant height (cm)	0.19	0.13	1	0.22	0.45**	0.40**	0.24	-0.02	0.23	-0.25	0.17	-0.22	-0.42**	-0.31*
Stem girth (mm)	-0.17	-0.26*	0.20	1	0.09	0.33*	0.55**	0.34**	0.44**	0.15	0.42**	0.30*	-0.14	-0.29*
Number of leaves per plant	0.28*	0.22	0.38**	0.07	1	0.44**	0.15	0.06	-0.03	-0.16	-0.07	-0.22	-0.13	-0.22
Leaf length (cm)	0.07	-0.20	0.33*	0.26*	0.33**	1	0.60**	0.14	0.28*	0.05	0.24	0.03	-0.11	-0.26*
Leaf breadth (cm)	-0.16	-0.40**	0.22	0.48**	0.15	0.54**	1	0.36**	0.46**	0.21	0.45**	0.26*	-0.10	-0.32*
Total soluble solids (%)	-0.16	-0.27*	-0.02	0.30*	0.05	0.15	0.34**	1	0.25	0.17	0.24	0.22	0.01	-0.15
Green fodder yield per plant (g)	-0.24	-0.31*	0.19	0.38**	-0.01	0.22	0.42**	0.22	1	0.46**	1.00**	0.15	-0.27*	-0.11
Grain yield per plant (g)	-0.25	-0.32*	-0.23	0.16	-0.14	0.04	0.19	0.15	0.37**	1	0.48**	0.11	0.71**	0.23
Dry fodder per plant (g)	-0.31*	-0.37**	0.15	0.36**	-0.04	0.19	0.41**	0.20	0.96**	0.41**	1	0.17	-0.25	-0.08
Test weight in (g)	-0.12	-0.17	-0.21	0.25	-0.20	0.02	0.24	0.20	0.11	0.08	0.14	1	-0.00	0.14
Harvest index (%)	-0.04	-0.07	-0.35**	-0.08	-0.12	-0.08	-0.10	0.02	-0.34**	0.69**	-0.33*	-0.01	1	0.37**
Protein content (%)	-0.03	0.04	-0.29*	-0.26*	-0.19	-0.21	-0.29*	-0.14	-0.09	0.22	-0.07	0.14	0.33*	1

*($p < 0.05$); **($p < 0.01$)

Table 5. Genotypic path analysis for grain yield per plant (g)

Character	Days to 50% flowering	Days to maturity	Plant height (cm)	Stem girth (mm)	Number of leaves per plant	Leaf length (cm)	Leaf breadth (cm)	Total soluble solids (%)	Dry fodder per plant (g)	Test weight in (g)	Protein content (%)	r_g
Days to 50% flowering	**0.01**	-0.05	-0.06	-0.01	0.01	0.00	-0.02	-0.01	-0.19	0.02	-0.02	-0.32*
Days to maturity	0.01	**-0.06**	-0.05	-0.01	0.01	-0.00	-0.05	-0.01	-0.22	0.03	0.01	-0.36**
Plant height (cm)	0.00	-0.01	**-0.33**	0.01	0.01	0.01	0.03	-0.00	0.08	0.03	-0.08	-0.25
Stem girth (mm)	-0.00	0.02	-0.07	**0.04**	0.00	0.01	0.06	0.01	0.20	-0.04	-0.07	0.15
Number of leaves per plant	0.00	-0.01	-0.15	0.00	**0.02**	0.01	0.02	0.00	-0.03	0.03	-0.05	-0.16
Leaf length (cm)	0.00	0.01	-0.13	0.01	0.01	**0.02**	0.07	0.01	0.12	-0.00	-0.06	0.05
Leaf breadth (cm)	-0.00	0.03	-0.08	0.02	0.00	0.01	**0.11**	0.01	0.22	-0.04	-0.08	0.21
Total soluble solids (%)	-0.00	0.02	0.01	0.01	0.00	0.00	0.04	**0.04**	0.11	-0.03	-0.04	0.17
Dry fodder per plant (g)	-0.00	0.03	-0.06	0.02	-0.00	0.00	0.05	0.01	**0.48**	-0.02	-0.02	0.48**
Test weight (g)	-0.00	0.01	0.07	0.01	-0.01	0.00	0.03	0.01	0.08	**-0.14**	0.04	0.11
Protein content (%)	-0.00	-0.00	0.10	-0.01	-0.01	-0.00	-0.04	-0.01	-0.04	-0.02	**0.25**	0.23

Residual = 0.7693; Bold value indicates direct effect; *(p <0.05); **(p <0.01)

Table 6. Phenotypic path analysis for grain yield per plant (g)

Character	Days to 50% flowering	Days to maturity	Plant height (cm)	Stem girth (mm)	Number of leaves per plant	Leaf length (cm)	Leaf breadth (cm)	Total soluble solids (%)	Dry fodder per plant (g)	Test weight in (g)	Protein content (%)	r_p
Days to 50% flowering	**0.01**	-0.07	-0.05	-0.02	-0.00	0.00	-0.01	-0.01	-0.12	0.02	-0.01	-0.25
Days to maturity	0.01	**-0.11**	-0.03	-0.02	-0.00	-0.00	-0.03	-0.01	-0.14	0.02	0.01	-0.32*
Plant height (cm)	0.00	-0.01	**-0.26**	0.02	-0.01	0.01	0.02	-0.00	0.05	0.03	-0.07	-0.23
Stem girth (mm)	-0.00	0.03	-0.05	**0.09**	-0.00	0.01	0.04	0.01	0.13	-0.03	-0.07	0.16
Number of leaves per Plant	0.00	-0.02	-0.10	0.01	**-0.02**	0.01	0.01	0.00	-0.02	0.03	-0.05	-0.14
Leaf length (cm)	0.00	0.02	-0.09	0.02	-0.01	**0.02**	0.05	0.01	0.07	-0.00	-0.05	0.04
Leaf breadth (cm)	-0.00	0.04	-0.06	0.05	-0.00	0.01	**0.09**	0.02	0.15	-0.03	-0.07	0.19
Total soluble solids (%)	-0.00	0.03	0.00	0.03	-0.00	0.00	0.03	**0.05**	0.07	-0.03	-0.03	0.15
Dry fodder per plant (g)	-0.00	0.04	-0.04	0.03	0.00	0.00	0.04	0.01	**0.37**	-0.02	-0.02	0.41**
Test weight (g)	-0.00	0.02	0.06	0.02	0.00	0.00	0.02	0.01	0.05	**-0.13**	0.03	0.08
Protein content (%)	-0.00	-0.00	0.08	-0.02	0.00	-0.00	-0.03	-0.01	-0.03	-0.02	**0.25**	0.22

Residual = 0.8196; Bold value indicates direct effect; *(p <0.05); **(p <0.01) direct effect on grain yield per plant was exhibited by dry fodder yield per plant and also the positive indirect effects via leaf breadth and days to maturity, and stem girth on grain yield per plant. In contrast, a high negative direct effect was exerted by plant height followed by test weight. The positive and significant correlation between dry fodder yield per plant and grain yield per plant was mainly due to its highly positive direct effect and also due to positive indirect effects via leaf breadth, days to maturity and stem girth. Besides, stem girth and leaf breadth could lead to considerable improvement of dry fodder yield in sorghum. These findings were akin to the findings obtained by Sukhchain and Singh (2008), Shinde *et al.* (2011), El-Din *et al.* (2012), Jain and Patel (2014), Patil *et al.* (2014), Khandelwal *et al.* (2015), Toor (2020), Sheetal (2021), Vinodhini *et al.*(2022) and Patil *et al.* (2023).

Conclusion

It can be stated from the current experiment that an adequate extent of variability was found in genetic material for all the traits under study. The traits, *viz.*, soluble solids (%), grain yield per plant (g), leaf breadth (cm) and dry fodder yield per plant (g) should be given due consideration during direct selection and the traits, *viz.*, dry fodder yield per plant, harvest index, green fodder yield per plant, leaf breadth, protein content and plant height might be considered as indirect selection indices. Hence, due concern should be given to these characters while planning a breeding strategy for increased yield of fodder and dual-purpose sorghum.

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