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Full Length Research Paper

Character association and inheritance studies of different sorghum genotypes for fodder yield and quality under irrigated and rainfed conditions

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Cyanide poisoning is the major problem in sorghum fodder. This poisoning results in livestock mortality and causes economic loss to the people. Some work have been reported on quantity but little work has been focused on quality especially the cyanide content in sorghum fodder in Pakistan. Inheritance mechanism for some fodder yield and quality traits were studied among 25 sorghum genotypes under irrigated and rainfed conditions. Highly significant genotypic as well as genotype x location differences were observed for all the characters studied. Highest genotypic and phenotypic variances were observed for plant height, fresh weight plant^{-1}, green fodder yield and total cyanide content. Green fodder yield, dry matter yield, fresh weight plant^{-1}, dry weight plant^{-1} and total cyanide content depicted high heritability estimates along with high expected genetic advance. There were strong positive genotypic and phenotypic correlations between green fodder yield and number of tillers plant^{-1} stem thickness, fresh weight plant^{-1}, dry weight plant^{-1} and dry matter yield. Strong negative genotypic and phenotypic correlations were observed between total cyanide content and number of tillers plant^{-1}, stem thickness, fresh weight plant^{-1}, dry weight plant^{-1} and green fodder yield. The present study indicates that the indirect selection and simultaneous improvement in sorghum fodder yield as well as quality is feasible because of significant relationship among traits.

Key words: Correlation-fodder yield-genetic advance-heritability-hydrocyanic acid, quality traits-*Sorghum bicolor*.

INTRODUCTION

Agriculture is the back bone of the economy of Pakistan. Agricultural crops and livestock play a fundamental role in the domestic production of the country. Consistent supply of high quality forage is essential to maintain high levels of milk and meat production (Tahir et al., 2005). The performance of dairy animals depends on the continuous availability of quality fodder in adequate amount.

Therefore, the critical limitation on profitable animal production in developing countries is the insufficient availability of quality forage (Sarwar et al., 2002).

Sorghum (*Sorghum bicolor* L.) is an important crop grown for both fodder and grain under irrigated as well as rainfed areas. Sorghum is successful fodder crop in rainfed areas due to its drought tolerance capability. Sorghum is highly variable in terms of genetic resources and germplasm that allows the breeding and development of new cultivars adapted to different agro-ecological regions around the globe (Zhang et al., 2010). Average fodder yield at present under local conditions of Punjab (Pakistan) is less than the potential of 50 to 100 tons per hectare (Chaudhry et al., 2006). The performance of sorghum even under rainfed conditions is significantly associated with plant height (Habyarimana

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Table 1. List of 25 sorghum genotypes and their source.

S/N	Genotype	Source of collection
1	LOCAL	CSI, NARC, Islamabad*
2	SV-1	CSI, NARC, Islamabad
3	RASILI	CSI, NARC, Islamabad
4	RARI-S-3	CSI, NARC, Islamabad
5	SV-5	CSI, NARC, Islamabad
6	DS-97	CSI, NARC, Islamabad
7	SV-4	CSI, NARC, Islamabad
8	JOHAR-1	CSI, NARC, Islamabad
9	RARI-S-4	CSI, NARC, Islamabad
10	RARI-SV-10	CSI, NARC, Islamabad
11	JV-2002	FRI, Sargodha**
12	SV-11	CSI, NARC, Islamabad
13	RS-29	CSI, NARC, Islamabad
14	SV-6	CSI, NARC, Islamabad
15	CVS-13	CSI, NARC, Islamabad
16	V-1	CSI, NARC, Islamabad
17	CSV-15	CSI, NARC, Islamabad
18	SV-7	CSI, NARC, Islamabad
19	SV-8	CSI, NARC, Islamabad
20	JS-2002	FRI, Sargodha
21	ENTOSOL	CSI, NARC, Islamabad
22	PARC-SS-2	CSI, NARC, Islamabad
23	SPV-462	CSI, NARC, Islamabad
24	YSS-9	CSI, NARC, Islamabad
25	RARI-S-10	CSI, NARC, Islamabad

*, Crop Sciences Institute, National Agricultural Research Centre, Islamabad; **, Fodder Research Institute, Sargodha.

et al., 2004). Green fodder yield showed positive and significant association with plant height. This specifies that any selection based on this trait will enhance the chances of improvement in forage sorghum. High genotypic and phenotypic variance was observed for the characters fodder yield and plant height demonstrating that additive gene effects were operating for these traits (Godbharle et al., 2010). Hydrocyanic acid is produced rapidly when plants under go environmental stress and disruption of leaf tissues. It is instantly absorbed into the blood stream of grazing animals and causes cellular asphyxiation and eventually the death of the animal.

Improvement in sorghum yield depends on the nature and extent of genetic variability, heritability and genetic advance in the base population (Mahajan et al., 2011). The study of relationship among quantitative traits is essential to assess the feasibility of joint selection for two or more traits. A positive genetic correlation between two desirable traits makes it easy to improve both the characters under consideration simultaneously (Khairwal et al., 1999). The objective of present study was to determine genetic potential of different sorghum genotypes for hydrocyanic acid content and to find out inheritance mechanism in different sorghum genotypes for fodder yield and quality under irrigated and rainfed conditions.

MATERIALS AND METHODS

Experimental design and location

The investigation material consisted of 25 sorghum genotypes were collected from Crop Science Institute, National Agricultural Research Centre, Islamabad and Fodder Research Institute, Sargodha (Table 1). The sorghum genotypes were sown in a randomized complete block design with three repeats during July 2009 at Arid Zone Agriculture Research Institute (AZRI), Bhakkar under irrigated conditions and at Koont Research Farm, PMAS-Arid Agriculture University Rawalpindi (PMAS-AAUR) under rainfed conditions. In both, the trials row length was kept at 4 m and row to row distance was maintained at 30 cm. Seed rate used was 80 kg/ha. Three irrigations were applied to the irrigated trial; first at 21 days after germination, second at 35 days after germination and third at full vegetative growth. All the recommended agronomic practices were carried out for better crop stand in both the trials. Meteorological data of both locations is given in Table 2.

Data collection and analytical method

Data regarding different plant traits were recorded during cropping

Table 2. Meteorological data of district Bhakkar and Chakwal for sorghum cropping season, 2009.

Month	*AZRI, Bhakkar (irrigated)			Koont Research Farm, **PMAS-AAUR (rainfed)		
	Rainfall (mm)	Temperature (°C)		Rainfall (mm)	Temperature (°C)	
		Minimum	Maximum		Minimum	Maximum
June	49.00	23.06	41.53	0.19	21.12	39.39
July	88.00	25.03	39.06	6.11	22.52	36.51
August	310.00	23.96	38.19	2.44	23.02	35.82
September	66.00	20.66	37.66	1.33	19.90	34.90
October	21.00	13.61	33.80	0.33	12.78	32.98
November	2.00	7.76	26.53	0.24	7.13	23.00
Mean	89.33	19.01	36.13	1.77	17.75	33.77

*, Arid Zone Agriculture Research Institute, Bhakkar; **, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi.

Table 3. Mean, range, standard error (S.E) and coefficient of variation (CV) for fodder yield components and hydrocyanic acid of 25 sorghum genotypes grown under irrigated and rainfed conditions of Punjab.

Parameter	Mean	Range	S.E.	C.V (%)
Plant height (cm)	145.02	94.20 - 203.40	1.90	7.87
Number of leaves plant^{-1}	12.00	9.00 - 17.80	0.14	7.92
No. of tillers plant^{-1}	1.72	1.00 - 3.00	0.04	9.96
Stem thickness (cm)	0.62	0.35 - 0.99	0.01	5.75
Fresh weight plant^{-1} (g)	50.03	21.25 - 81.25	1.03	6.38
Dry weight plant^{-1} (g)	15.04	6.66 - 31.92	0.40	7.76
Green fodder yield (t/ha)	36.33	10.75 - 57.40	0.74	5.51
Dry matter yield (t/ha)	10.87	3.67 - 20.12	0.27	6.44
-tal cyanide content (%)	487.59	197.21 - 666.62	8.60	5.59

S.E.,Standard error; C.V, coefficient of variation.

season and after harvest. The traits under evaluation were plant height (cm), number of leaves plant^{-1}, number of tillers plant^{-1}, stem thickness (cm), fresh weight plant^{-1}(g), dry weight plant^{-1}(g), greenfodder yield (t/ha), dry matter yield (t/ha) and total cyanide contents (ppm). Total cyanide content was determined by picrate paper method (Egan et al., 1998).

Data analysis

Data were subjected to analysis of variance (Steel et al, 1997) and covariance. Genetic (r_g), phenotypic (r_p) and simple (r) correlation coefficients were estimated (Kown and Torrie, 1964). The significance of correlation was tested by t-test. Broad sense heritability ($h^2{}_{BS}$) was calculated following Hanson et al. (1956) and heritability percentage was categorized as low, moderate and high (Robinson et al., 1949). Genetic advance as percent of the mean was worked out and categorized as low, moderate and high (Johnson et al., 1955).

RESULTS AND DISCUSSION

Estimation of Simple Variability

Mean, range, standard error and coefficients of variation (CV) of each evaluated trait are presented in Table 3. Mean values of plant height, number of leaves plant^{-1}, number of tillers plant^{-1}, stem thickness, fresh weight plant^{-1}, and green fodder yield was greater under irrigated conditions than the rainfed conditions, whereas the mean value of dry weight plant^{-1}, dry matter yield and total cyanide content was greater under rainfed conditions than the irrigated conditions. These results indicated that plant height, number of leaves plant^{-1}, number of tillers plant^{-1}, stem thickness, fresh weight plant^{-1} and green fodder yield decreases but dry weight plant^{-1}, dry matter yield and total cyanide content increases under water stress.

The lowest CV was observed for green fodder yield (5.51%) and the highest for number of tillers plant^{-1} (9.96%). Overall, the CV for all the characters remained in an acceptable range. Stem thickness showed the lowest (0.01) while the total cyanide content showed the highest (8.60) standard error.

CV is an index of reliability and indicates the magnitude of experimental error. The lower the values of CV, the more the results are reliable and vice versa.

Analysis of variance

The means squares for genotype (MS_g), genotype x

Table 4. Mean square values for fodder yield components and hydrocyanic acid in 25 sorghum genotypes grown under irrigated and rainfed conditions of Punjab.

Parameter	MS_g	MS_l	MS_{gl}	MS_e
Plant height (cm)	1672.643**	18459.306**	330.494**	130.329
Number of leaves plant^{-1}	4.861**	126.960**	3.187**	0.904
No. of tillers plant^{-1}	0.813**	9.425**	0.266**	0.029
Stem thickness (cm)	0.038**	1.208**	0.038**	0.001
Fresh weight plant^{-1} (g)	908.547**	296.750**	19.393*	10.203
Dry weight plant^{-1} (g)	136.205**	72.093**	5.020**	1.362
Green fodder yield (t/ha)	449.496**	724.109**	8.330**	4.007
Dry matter yield (t/ha)	62.297**	2.755*	2.917	0.491
Total cyanide content (%)	57108.189**	477883.961**	2478.163**	741.719

*, Significant at 5% level of significance; **, highly significant at 1% level of significance; MS_g, Mean squares for genotypes; MS_l, mean squares for location; MS_{gl}, mean squares for genotype x location; MS_e, mean squares for error.

Table 5. Estimates of variance components and derivative genetic parameters in 25 sorghum genotypes grown under irrigated and rainfed conditions of Punjab.

Parameter	δ^2g	δ^2e	δ^2p	GCV (%)	PCV (%)	h^2_{BS} (%)	EGA (%)
Plant height (cm)	223.69	130.3	278.77	10.31	11.51	80.24	16.21
Number of leaves/plant	0.28	0.90	0.81	4.40	7.50	34.45	4.53
No. of tillers /plant	0.091	0.03	0.14	17.55	21.39	67.31	25.27
Stem thickness (cm)	0.017	0.001	0.02	20.80	24.45	72.36	31.05
Fresh weight/plant (g)	148.19	10.20	151.43	24.33	24.60	97.87	42.24
Dry weight /plant (g)	21.864	1.36	22.70	31.09	31.68	96.31	53.55
Green fodder yield (t/ha)	73.53	4.01	74.92	23.60	23.82	98.15	41.04
Dry matter yield (t/ha)	9.90	0.49	10.38	28.94	29.64	95.32	49.59
Total cyanide content (%)	9105	741.7	9518.0	19.57	20.01	95.66	33.59

δ^2g, Genotypic variance; δ^2e, environmental variance; δ^2p, phenotypic variance; GCV, genotypic coefficient of variation, PCV, phenotypic coefficient of variation; h^2_{BS}, broad sense heritability in percent; EGA, expected genetic advance.

location (MS_{gl}) and error (MS_e) are presented in Table-4. All the genotypes showed considerable amount of genotypic differences in their mean performance with respect to all the traits studied. Genotypes x location mean squares were highly significant for all traits except for dry matter yield.

In present evaluation highly significant differences among the genotypes indicated the presence of sufficient amount of variability which provides scope for selection of superior and desirable genotypes regarding quantity and quality of sorghum fodder. Mohanraj *et al*. (2006) reported highly significant differences among the sorghum accessions for plant height, number of leaves plant^{-1} and fodder yield indicating the presence of sufficient genetic variability for these traits.

Genotypic and phenotypic variation

The estimates of components of genotypic variance and its derivative genetic parameters, heritability and genetic advance for fodder yield and other traits are presented in Table 5. Total cyanide content (9105 and 9518%), plant height (223.69 and 278.77%), fresh weight plant^{-1} (148.19 and 151.43%) and green fodder yield (73.53 and 74.92%) showed the highest and stem thickness (0.017 and 0.02%) the lowest in genetic and phenotypic variances. The highest values of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were found for dry weight plant^{-1} (31.09 and 31.68%), dry matter yield (28.94 and 29.64%), fresh weight plant^{-1} (24.33 and 24.60%), green fodder yield (23.60 and 23.82%) and stem thickness (20.80 and 24.45%).

Moderate estimates of GCV and PCV were observed for number of tillers plant^{-1} (17.55 and 21.55%) and total cyanide content (19.57 and 20.01%) and the lowest for number of leaves plant^{-1} (4.40 and 7.50%).

The results of this study indicated that genotype x environment interactions were found significant for all the traits under study. When the genotype x environmental interaction is signi-ficant, the simple effects like that of genotype and location separately become meaningless

Table 6. Simple correlation among fodder yield and hydrocyanic acid in 25 sorghum genotypes grown under irrigated and rainfed conditions of Punjab.

Parameter	NL/P	NT/P	ST	FW/P	DW/P	GFY	DMY	TCC
PH	0.25**	0.32**	0.29**	0.12	0.10	0.24**	0.20*	-0.30**
NL/P		0.37**	0.19*	0.03	-015	0.02	-0.16	-0.07
NT/P			0.68**	0.32**	0.13	0.46**	0.25**	-0.64**
ST				0.36**	0.12	0.47**	0.22**	-0.70**
FW/P					0.88**	0.65**	0.64	-0.61**
DW/P						0.56**	0.79**	-0.48**
GFY							0.86**	-0.75**
DMY								-0.62**

*, Significant at 5% level of significance; **, highly significant at 1% level of significance; PH, plant height; NL/P, number of leaves plant^{-1}; NT/P, number of tillers plant^{-1}; ST, stem thickness; FW/P, fresh weight plant^{-1};DW/P, dry weight plant^{-1}; GFY, green fodder yield; DMY, dry matter yield; TCC, total cyanide contents.

because it reduces the association between phenotypic and genotypic values and the selection made at one location will perform poorly at the other location or environment. If the genotype x environmental interaction is not taken into consideration, it causes an upward unfairness in the estimate of genotypic variance.

These findings suggest that the environmental conditions in two locations influenced the performance of genotypes under study as evidenced by Bello et al. (2007).

Phenotypic coefficient of variation was greater than the genotypic variation in this study. Higher phenotypic coefficient of variation (PCV) than the genotypic coefficient of variation (GCV) indicated greater influence of environment. Sharma *et al*. (2006) observed strong genotypic and phenotypic coefficient of variation for fodder yield and plant height in sorghum.

Heritability and genetic advance

The estimates of expected genetic advance and heritability for green fodder yield and other traits are presented in Table 5. High heritability together with high genetic advance estimates was reported for the characters; green fodder yield (98.15 and 41.04%), fresh weight plant^{-1} (97.87 and 42.24%), dry weight plant^{-1} (96.31 and 53.55%), total cyanide content (95.66 and 33.59%) and dry matter yield (95.32 and 49.59%).

High heritability along with high expected genetic advance during this evaluation pointed out the prevalence of additive gene effect which is less affected by environment. The phenotypic selection for characters like fresh weight plant^{-1}, dry weight plant $^{-1}$, green fodder yield, dry matter yield and total cyanide content having high heritability estimates along with high genetic advance will be effective thus due importance should be given to these characters. Heritability can be determined with greater precision if it is studied with genetic advance and expected genetic advance. Godbharle et al. (2010) detected high heritability and genetic advance for the characters fodder yield and plant height indicating that additive gene effects were operating for these traits.

Correlation studies

Simple correlation

The simple correlation coefficients (r) are presented in Table 6. Total cyanide contents had highly significant negative correlation with plant height (-0.30), number of tillers plant^{-1} (-0.64), stem thickness (-0.70), fresh weight plant^{-1} (-0.61), dry weight plant^{-1} (-0.48), green fodder yield and dry matter yield. Highly significant and positive correlation was observed between green fodder yield and plant height (0.20), number of tillers plant^{-1} (0.25), stem thickness (0.22), fresh weight plant^{-1} (0.64), dry weight plant^{-1} (0.79) and dry matter yield (0.86).

The findings of this study indicated that there was significant and positive correlation among fodder yield and its components, whereas total cyanide content had significant and negative association with fodder yield and all of its components. An improvement in fodder yield components will indirectly improve the green fodder yield as well as quality of the fodder with reduction in hydrocyanic acid content. Keeping in view these findings, the indirect selection for improvement in green fodder yield and hydrocyanic acid content in sorghum fodder appears possible. Iyanar et al. (2010) showed that dry fodder yield exhibited high correlation coefficient with green fodder yield, plant height and number of leaves plant^{-1}. Dry matter yield can be improved by indirect improvement in positively associated fodder yield components. Prabhakar and Reddy (2007) explained that the dry fodder yield and some major fodder yield components showed high positive correlation with stem fresh weight, number of leaves, plant height and stem thickness.

Table 7. Genotypic (r_g) and phenotypic (r_p) correlation coefficients among fodder yield and hydrocyanic acid in 25 sorghum genotypes grown under irrigated and rainfed condition of Punjab.

Parameter	PH	NL/P	NT/P	ST	FW/P	DW/P	GFY	DMY	TCC
PH		0.16	0.24	0.12	0.11	0.21	0.19	0.29	-0.29
NL/P	0.07		0.00	0.32	-0.19	-0.31	-0.51**	-0.51**	0.24
NT/P	0.15	0.07		0.91**	0.46*	0.31	0.55**	0.41*	-0.75**
ST	0.10	0.05	0.82**		0.53**	0.36	0.62**	0.46*	-0.89**
FW/P	0.11	-0.09	0.46*	0.43*		0.93*	0.65**	0.69**	-0.68**
DW/P	0.21	-0.17	0.33	0.29	0.92**		0.63**	0.78**	-0.62**
GFY	0.17	-0.27	0.57**	0.51**	0.65**	0.63**		0.93**	-0.84**
DMY	0.27	-0.29	0.43*	0.36	0.67**	0.78**	0.92**		0.77**
TCC	-0.25	0.15	-0.78**	-0.76**	-0.66**	-0.60**	-0.80**	0.73**	

*, Significant at 5% level of significance; **, highly significant at 1% level of significance. Above diagonal: genotypic correlation coefficient (r_g). Below diagonal: phenotypic correlation coefficient (r_p).

Genotypic and phenotypic correlation

The r_g and r_p are presented in Table 7. Strong positive genotypic and phenotypic correlation was observed between green fodder yield and number of tillers plant^{-1} (0.55 and 0.57), stem thickness (0.62 and 0.51), fresh weight plant^{-1} (0.65 and 0.65), dry weight plant^{-1} (0.63 and 0.63) and dry matter yield (0.93 and 0.92), indicating that an increase in green fodder yield was because of increase in one or more of the above characters. Similarly, highly significant genotypic and phenotypic correlation was observed between dry matter yield and number of tillers plant^{-1} (0.41 and 0.43), fresh weight plant^{-1} (0.69 and 0.67) and dry weight plant^{-1} (0.78 and 0.78). Powerful and positive genotypic and phenotypic correlation was observed between total cyanide content and dry matter yield (0.77 and 0.73) but genotypic and phenotypic association between total cyanide content and number of tillers plant^{-1} (-0.75 and -0.78), stem thickness (-0.89 and -0.76), fresh weight plant^{-1} (-0.68 and -0.66), dry weight plant^{-1} (-0.62 and -0.60), green fodder yield (-0.84 and -0.80) was found to be negative and highly significant.

The r_g were generally of higher magnitude than rp in this study indicating the inherited association between various traits.

Godbharle et al. (2010) found that fodder yield plant^{-1} had positive and strong genotypic and phenotypic correlation with plant height.

Conclusion

In present study, there was sufficient genetic variability among the genotypes. The genotypic and phenotypic variances were greater than the variance due to environment for all the traits under study. Greater genetic variance provides an opportunity for a stable improvement in the desired trait of the crop. r_g were of higher magnitude than r_p for almost all the traits indicating innate association among the characters under evaluation. Hydrocyanic acid has negative correlation with fodder yield and its components. Keeping in view, the correlation studies, the improvement of fodder yield and quality through indirect selection of fodder yield components is feasible. It is therefore suggested that fodder yield must be improved in future research work and cyanide poisoning will be reduced due to negative correlation with fodder yield.

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