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EXPLOITING THE HETEROSIS AND CORRELATION ANALYSIS STUDIES IN FORAGE SORGHUM FOR QUALITY IMPROVEMENT

REENU[1], SATYAWAN ARYA[1], MANISHA[2], KAVITA RANI[1], PRIYANKA DAHIYA[3] AND ATMAN POONIA[1,*]

[1]Department of Genetics and Plant Breeding,
CCS Haryana Agricultural University, Hisar-125004 (Haryana), India
[2]ICAR-Central Soil Salinity Research Institute, Karnal-132 001 (Haryana), India
[3]Sher-e-Kashmir University of agriculture Sciences and Technology Jammu, J&K, India
*(*e-mail : atmanpoonia@gmail.com*)

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ABSTRACT

Sorghum is widely grown as a semi-arid infallible fodder crop for livestock consumption. The availability of better quality green fodder for prolonged periods is directly associated with the lactation efficiency in animals which ultimately leads to the self sufficiency in milk production. The present investigation was conducted at Forage Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar during the *Kharif* season of 2019 for the estimation of amount of heterosis, heterobeltiosis and correlation between quality parameters of forage sorghum. The experimental material consisted of 18 F_1hybridsdeveloped by crossing three lines and six testers in L×T design. The crosses 9A × G 46 (-52.88%), 9A × HJ 541 (50%),14A × S 437 (-16.85%),9A × S 437 (-16.83%), 9A × S 437 (-16.99%), 9A × GFS 5 (-45.45%), 31A × G 46 (-64.56%, -68.53%) and SSG 59-3 (-42.57%) exhibited the high significant heterosis for sorghum quality parameters like crude protein, total soluble solids (TSS),hydrocyanic acid (HCN), crude protein, neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose, lignin, tannin and phenol, respectively. The significant correlation observed between HCN, crude protein, NDF, ADF and cellulose contents indicating the scope of these crosses for the crop improvement. These findings can be applied to develop high heterotic hybrids with better forage quality for animal nutrition.

Key word : Hybrids, quality nutrition, correlation, heterosis, HCN, crude protein

Sorghum [*Sorghum bicolor* (L.) Moench] is the 5th important cereal crop globally after wheat, rice, maize and barley grown for food, feed, fodder and bio-energy purposes. It is mainly grown in the arid and semi-arid tropics for green fodder requirement during *kharif* and *rainy* season (Hall *et al.* 2004). To increase the per capita milk availability with increasing population and limited land resources under changing environmental conditions indicating the requirement of better quality animal nutrition. Although India is leading milk producing country in the world but due to the limitation of quality fodder and nutrition supply during entire season, per capita milk production is very low. Therefore, the critical limitation on profitable animal production in developing countries is the insufficient availability of quality forage (Sarwar*et al.*, 2002).

Crude protein content is positively associated with the fodder quality but this is not the sole measure of forage quality and can be deceiving. HCN, lignin content, and phenolic compounds should be consider to improve the nutritive value of forage sorghum for productive ruminants.The amount of anti-nutritional cyanoglycoside present in sorghum feed has toxic effects on livestock feeding due to breakdown of cyanoglycoside into hydrocyanic acid by digestive enzymes (Al-Beiruty *et al.* 2020). Energy content depends on the digestibility of various chemical fractions of forages. The most common method of predicting forage energy content is based on amount of fiber. Plants that contain large amounts of neutral detergent and acid detergent fibers are generally less digestible. Fiber is more variable in digestibility than other soluble fractions of the plant such as sugars and is currently the most accurate predictor of forage energy content. Lignin affects the digestibility of forage in animals and is considered both an unfavourable component of forages and an anti-nutritive in animals (Frei, 2013).

Reducing lignin and anti-nutritional factor while increasing non-structural carbohydrates, crude protein and palatability, are current priorities in breeding, in order to improve digestibility by livestock (ANFs; Krämer-Schmid *et al*., 2016; Wilkins, 2018). Digestibility is decreased by tannins binding to either digestive enzymes or tothe proteins themselves. Sorghum with tannins decreases feed efficiency by 5%-20% when fed to livestock depending on feeding system and livestock species.Reduction in dry matter intake and in the digestion of protein and fiber is an adverse effect often associated with tannins (Schofield et al., 2001; Makkar, 2003).

NDF fraction consists of hemi-cellulose, cellulose, lignin, and silica/minerals. Cellulose (a long chain of glucose molecules linked end to end) and hemi-cellulose (a branched polymer of glucose, xylose, galactose, and other carbohydrates) can be broken down by enzymatic action of bacteria and other microbes in the animal's digestive tract, though their digestion is markedly slower than the digestion of sugars, starches, and other freely available non-structural carbohydrates. In contrast, lignin is not carbohydrate-based but is a phenolic compound. As such, lignin is not digestible. Moreover, the very presence of lignin acts as a physical barrier to the microbial enzymes that break down cellulose and hemi-cellulose. Polyphenols are the secondary metabolites produced and they inhibit protein digestibility as they bind the proteins and make them unavailable for the intestinal absorption.

Owing to the available germplasm resources, it is required to exploit them for the yield and quality parameters through different breeding programmes (Akabari and Parmar 2014). Heterosis breeding is one of the universally accepted schemes for enhancing the yield and quality parameters in agriculture. So far, a detailed study is not conducted on the improvement of forage quality along with the yield associated traits. Therefore, the present investigation was conducted to determine the superior heterotic hybrids which can be further utilized in the breeding programmes for development of high yielding varieties with better quality.

MATERIALS AND METHODS

Genetic Material : To obtain better quality and nutrient rich fodder, the experimental material comprised of forage sorghum hybrids which included nine parents (three females 9A, 14A, 31A and six males HJ 541, GFS 5, G 46, SGL 87, S 437, SSG 59-3) and two standard checks (CSH 24MF and SSG 59-3) was laid out in Randomized complete block design (RBD) with 3 replications. The crosses were attempted in Line × Tester fashion on three females (lines) and six males (Testers) used to develop hybrids.

Experiment site and location : The study was conducted in research area of Forage Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar during the *Kharif* season of 2019. It is situated in semi-arid, sub-tropical region at 29.09^0N latitude and 75.43^0E longitude with elevation of 215 m (705 ft) above mean sea level.

Observations recorded: Total soluble solids (TSS) were measured by Refractometer. The samples for HCN estimation were collected at 30 Days to sowing (DAS) from the portion of the tiller immediately below the uppermost leaf collar, using the method given by (Gilchrist *et al.,* 1967). Total nitrogen content was estimated by the micro-Kjeldahl method and crude protein content was determined by multiplying the nitrogen content by a factor of 6.25. Cell content and cell wall constituents like Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) and Cellulose contents were determined by the procedure given by Singh and Pradhan, 1981. The total phenol was estimated using the method of Swain and Hillis (1959).

Statistical Analysis: Correlation was estimated between different quality characters with R-studio software, while estimation of economic heterosis and heterobeltiosis calculated using EXCEL with following formulas

$$\text{Economic Heterosis (\%)} = \frac{F1 - CC}{CC} \times 100$$

$$\text{Heterobeltiosis (\%)} = \frac{F1 - BP}{BP} \times 100$$

Where, CC = mean performance of commercial cultivar, F_1 = mean performance of a cross.
BP = mean performance of better parent

RESULTS AND DISCUSSION

In this study, two types of heterosis i.e. standard heterosis and heterobeltiosis were estimated for forage quality characters. The estimates of heterosis for different characters are depicted in Table 1. For the estimation of standard heterosis, two released hybrids (CSH 24MF and SSG 59-3) were used as checks and heterobeltiosis was estimated over better parent.

Hydrocyanic acid and Crude protein content estimation

HCN content in forage sorghum is an anti-nutritional factor and it can be toxic to animals. So, a significant amount of heterosis in a negative direction is desirable to feed livestock. Highest desirable heterosis for HCN were recorded in cross 9A × G 46 (-52.88%, -39.3%) over better parent and CSH 24MF, respectively. The extent of heterosis ranged from -52.88% to 104.4% and crosses that exhibit negative significant heterosis for HCN content were 9A × G 46 , 9A × GFS 5, 9A × SGL 87, 14A × HJ 541, 14A × G 46, 14A × SSG 59-3. Similar heterosis in negative direction had been reported by Patel *et al*. (2011) and Dehinwal *et al.* (2017), which indicated the scope of improvement for low HCN hybrids.

Highest amount of significant economic heterosis for crude protein was exploited by hybrid 9A × HJ 541 (50%, 36.59%, 31.71%) over SSG 59-3 check, better parent and CSH 24MF check, respectively. The Extent of heterosis ranged from -21.14% to 50%. Crude protein content is of utmost importance as it largely determines the palatability and nutrition value of forage crops. These results about crude protein content in present study are in concurrence with previous findings of Filho *et al.* (2004) and Nabi *et al.* (2006).

Neutral Detergent Fiber, Acid Detergent Fiber and Cellulose

High levels of fiber content in the fodder adversely affect the digestion of forage sorghum, so for better digestibility heterosis in the negative direction is desirable for NDF and ADF. Significant amounts of heterosis in negative direction for NDF over check SSG59-3 were shown by cross 14A × S 437 (-16.85%), 31A × S 437 (-9.21%) and 14A × SGL 87 (-4.07%) while over better parent significant heterosis was shown by cross 14A × S 437 (-12.79%). For ADF crosses that show high significant negative heterosis were 9A × S 437 (-16.83%) followed by 9A × SGL 87(-15.5%), 14A × G 46 (-14.9%), 31A × S 437 (-14.78%), 14A × S 437 (-13.08%) and 14A × SGL 87(-10.82%) over check SSG59-3 and over better parent, cross 14A × G 46 (-12.16%).

The NDF and ADF heterosis varied from -16.85% to 23.4% and -16.83% to 27.03%, respectively. Similar findings have been reported by Patel *et al*. (2011); Singh *et al.* (2014) and Mohammed *et al*. (2008). Extent of heterosis for cellulose ranged from -14.77% to 21.56%. Significant amounts of heterosis in negative direction for cellulose were shown by cross 9A × S 437 (-16.99%, -11.89%) over check SSG 59-3 and better parent respectively.

Lignin, Tannin and Phenol

Highest amount of significant heterosis in negative direction for lignin was shown by cross 9A × GFS 5 (-45.45%, -33.33%, -30.36%) over check CSH 24MF, SSG 59-3 and better parent, respectively. Cross 9A × S 437 (-36.36%, -22.22%, -21.82%) also had significant heterosis in negative direction over check CSH 24MF, SSG 59-3 and better parent, respectively. Extent of heterosis for lignin ranged from -33.90% to 23.73%. Significant amounts of heterosis in negative direction were shown by cross31A × G 46 (-64.56%, -68.53%) over check CSH 24MF and SSG 59-3 respectively. Other significant crosses were 14A × G 46 (-44.66%, -50.86%) and 14A × GFS 5 (-37.86%, -44.83%) over check CSH 24MF and SSG 59-3, respectively. Extent of heterosis for tannin ranged from -72.85% to 15.69%. Highest significant heterosis in negative direction over SSG 59-3 (-42.57%), CSH 24MF (-30.33%) and better parent (-28.57%) exhibited by cross 31A × SGL 87. Extent of heterosis for phenol ranged from -42.57% to 55.74%.

Correlation matrix

The correlation analysis was conducted to find out the association between different fodder quality traits which are directly or indirectly helpful in the improvement of desired trait. Correlation analysis revealed that the TSS was positively correlated with NDF (0.38) and tannin (0.21), which might be due to the increase in structural carbohydrates and decrease in non- structural carbohydrates **(Table 2)**. The significantly positive correlation was observed between ADF and NDF (0.5) while non-significant and negatively correlatrion was found between ADF and CP content. Similar finding had been reported by Sohail *et al*., (2007) and Prajapati *et al*., (2017) which reveals

TABLE 1
Extent of economic heterosis and heterobeltiosis for different quality characters in forage sorghum

Hybrids	Total soluble solids			Cellulose			Lignin			Tannin			Phenol		
	Ch1	Ch2	BP	Ch1	Ch2	BP	Ch1	Ch2	BP	Ch1	Ch2	BP	Ch1	Ch2	BP
9A × HJ 541	-17.3	-40.37**	-34.54*	6.71	-7.67	-3.51	5.11	28.47**	3.81	-33.59**	-41.03**	-49.13	36.89**	12.84**	34.68**
9A × GFS 5	14.38	-17.52	-10.01	8.97	-5.71	-1.76	-45.45**	-33.33**	-30.36**	-6.8	-17.24**	-28.60	13.44*	-6.49	22.48**
9A × G 46	5.85	-23.67	-7.56	9.14	-5.56	-1.62	4.55	27.78**	22.00**	-18.45*	-27.59**	-37.53	17.21**	-3.38	6.72
9A × SGL 87	-3.82	-30.64*	-16.00	15.4*	-0.15	-2.43	-22.73**	-5.56	-14.04*	-26.21**	-34.48**	-43.48	-8.2	-24.32**	-5.88
9A × S 437	22.9	-11.38	1.79	-4.07	-16.99**	-11.89*	-36.36**	-22.22*	-21.82**	-19.42**	-28.45**	-38.27	-22.13**	-35.81**	-15.93*
9A× SSG 59-3	8.52	-21.74	-5.22	10.88	-4.06	-1.73	-25**	-8.33	-17.24*	0.1	-11.21	-23.39	45.9**	20.27**	22.76**
14A × HJ 541	28.88	-7.06	2.01	5.84	-8.42**	3.05	9.09	33.33**	6.78	-21.36**	-30.17**	-39.76	27.87**	5.41	25.81**
14A × GFS 5	16.54	-15.96	-8.31	23.57**	6.92	24.58**	2.27	25.00*	7.14	-37.86**	-44.83**	-52.40	16.39**	-4.05	16.30**
14A × G 46	5.98	-23.58	-10.72	7.06	-7.37**	4.68	-6.82**	13.89	12.00	-44.66**	-50.86**	-57.61	4.92	-13.51**	-4.48
14A × SGL 87	-6.74	-32.75**	-21.44	25.3**	8.42	4.85	13.64	38.89**	14.04*	14.56*	1.72	-12.24	-1.64	-18.92**	-1.72
14A × S 437	12.34	-18.99	-6.95	4.8	-9.32	-0.28	-20.45*	-2.78	-9.09	-16.31*	-25.69**	-35.89	1.64	-16.22**	1.56
14A × SSG 59-3	-19.59	-42.02**	-32.26*	7.06	-7.37*	-4.66	-3.41	18.06	-0.86	-23.3**	-31.9**	-41.24	29.51**	6.76	8.97
31A × HJ 541	-11.07	-35.87**	-29.61*	11.05	-3.91	7.41	11.36	36.11**	8.47	-37.86**	-44.83**	-52.40	27.05**	4.73	25.00**
31A × GFS 5	-17.81	-40.73**	-35.34*	8.62	-6.02	10.18*	-15.91	2.78	-7.14	11.65	-0.86	-14.47	8.2	-10.81*	34.69**
31A × G 46	-30.03	-49.54**	-31.16	3.75	-10.23*	1.9	7.95	31.94**	20.19*	-64.56**	-68.53**	-72.85	6.56	-12.16*	-2.99
31A × SGL 87	-2.54	-29.72*	0.39	18**	2.11	-0.51	-15.91	2.78	-8.77	-27.18**	-35.34**	-44.22	-30.33**	-42.57**	-28.57**
31A × S 437	-6.74	-32.75**	-22.76	6.01	-8.27	0.71	-31.82**	-16.67	-18.18*	2.91	-8.62	-21.16	-8.2	-24.32**	9.80
31A× SSG 59-3	10.18	-20.55	13.05	15.22*	-0.3	1.60	-27.16**	-10.97	-18.88**	-6.8	-17.24**	-28.60	27.87**	5.41	7.59

Hybrids	Hydrogen cyanide			Crude protein			Neutral detergent fiber			Acid detergent fiber		
	Ch1	Ch2	BP	Ch1	Ch2	BP	Ch1	Ch2	BP	Ch1	Ch2	BP
9A × HJ 541	-14.51	14.87	-38.05	31.71**	50**	36.59**	23.4	8.55*	12.95**	4.33	17.3**	1.64
9A × GFS 5	-37.31**	-15.77	-31.29**	29.27**	47.22**	29.27**	8.3	-4.73	0.70	5.17	18.24**	11.52*
9A × G 46	-39.3**	-18.45	-52.88**	-7.32	5.56	-7.32*	20.09	5.64	11.67**	10.82*	27.03	14.39**
9A × SGL 87	4.38	40.24**	-47.7**	-11.59	0.69	-12.12**	11.6	-1.83	-3.51	-15.5**	-5.00	-7.62
9A × S 437	-2.70	30.72*	-32.83**	-15.85	-4.17	-15.85**	8.30	-4.73	0.70	-16.83**	-6.49	-9.07
9A× SSG 59-3	-17.88	10.34	-9.98	-4.88	8.33	-4.88	21.98	7.30*	4.70	-1.44	10.81*	3.02
14A × HJ 541	-12.34**	17.78	-36.48**	19.51**	36.11**	7.34*	17.92	3.73	7.94*	-4.33	7.57	-6.79
14A × GFS 5	-14.33	15.11	-16.75	4.88	19.44	-5.81	10.75	-2.57	2.18	6.49	19.73**	12.92*
14A × G 46	-17.00*	11.46	-35.60**	12.20**	27.78**	0.77	12.83	-0.75	4.09	-14.9**	-4.32	-12.16*
14A × SGL 87	10.25	48.13**	-44.76**	2.44*	16.67*	-8.00*	9.06	-4.07**	-5.71**	-10.82*	0.27	0.82
14A × S 437	13.59	52.61**	-21.58**	-10.98	1.39	-21.14**	-5.47	-16.85**	-12.79**	-13.08**	-2.27	2.73
14A × SSG 59-3	-30.08**	-6.06	-32.05**	-6.10	6.94	-15.66**	22.92	8.13*	5.51	-8.17	3.24	-4.02
31A × HJ 541	-19.92*	7.60	-44.42**	18.90*	35.42**	25**	15.38	1.49	5.61	-8.65	2.70	-11.01*
31A × GFS 5	14.98	54.48**	-20.2**	1.22	15.28	2.47	6.42	-6.39	-1.66	-14.18**	-3.51	-9.00
31A × G 46	22.63*	64.77**	-14.89*	-3.66	9.72	1.41	20.75	6.22	11.60**	10.22*	23.92**	13.77**
31A × SGL 87	52.14**	104.41	-23.77**	-14.63	-2.78	-15.15**	13.4	-0.25	-1.96	-12.38**	-1.49	-0.95
31A × S 437	12.49	51.13**	-22.34**	-8.54	4.17	-1.57	3.21	-9.21*	-4.62	-14.78**	-4.19	1.87
31A× SSG 59-3	28.36**	72.46	-10.91	-6.1	6.94**	1.05	11.51	-1.91	-4.29	-5.05	6.76	-0.75

Ch1= check 1 (CSH 24MF), Ch2= check 2 (SSG 59-3), BP= Better parent; * Significant at 5% level**Significant at 1% level.

TABLE 2
Correlation Matrix of forage quality traits

	TSS	HCN	CP	NDF	ADF	CL	Lignin	Tannin	Phenol
TSS	1								
HCN	-0.08	1							
CP	-0.04	-0.37**	1						
NDF	-0.38**	-0.29	0.30**	1					
ADF	-0.03	-0.37**	0.33*	0.50**	1				
CL	-0.24	0.06	0.02	0.22	0.15	1			
Lignin	-0.29	0.00	0.18	0.46*	0.33**	0.25**	1		
Tannin	-0.23**	0.18	-0.2*	-0.10	-0.18	0.37*	-0.13	1	
Phenol	-0.21	-0.47**	0.47*	0.58**	0.53**	0.24	0.27	0.18	1

TSS = Total soluble sugars, HCN = (Hydrocyanic acid), CP= Crude protein, NDF= Neutral detergent fiber, ADF= Acid detergent fiber, CL = Cellulose, * and ** Significant at 5 % and 1 % level, respectively.

that accumulated cell wall (NDF/ADF/Hemi-cellulose) contents are less digestible than cell soluble which be due to NDF/ADF/Hemi-cellulose contents simply act as physical barrier to microbial enzymes reacting their target polysaccharides. Crude protein content show significant positive correlation with cell wall contents NDF (0.3) and ADF(0.33), which is in conformity with earlier findings by Jancik *et al*., (2008) and Azo *et al*., (2012). Cellulose content was found positively correlated with lignin (0.25) and tannin (0.37) while HCN was significantly and negatively correlated with crude protein (-0.37), ADF (-0.37) and phenol (-0.47). Similar negative correlation between HCN and crude protein had been reported by Punia *et al*., (2021).

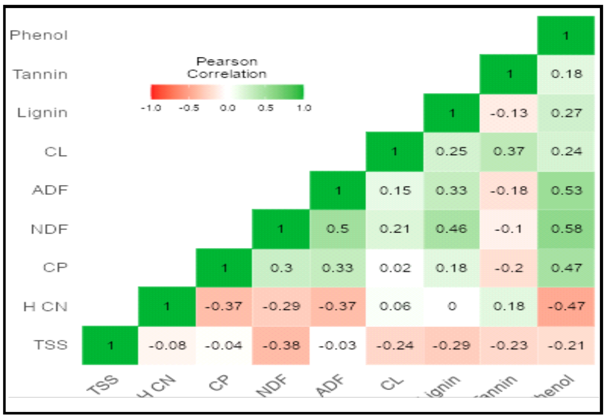

Fig. 1. Correlation heat map.

CONCLUSION

The present investigation indicated that crosses 9A × GFS 5, 14A × HJ 541, 31 A × HJ 541exhibited significantly negative heterosis for HCN content and positive heterosis for crude protein content. Although crosses 9A × S 437, 14A × S 437, 31A × S 437 were reported desirable significant negative heterosis for traits NDF, ADF, cellulose, lignin and phenol content. These hybrids can be evaluated further to develop quality forage sorghum hybrids. Due to presence of Significant negative correlation between HCN and crude protein content hybrids with high protein content and low HCN content can be selected. Moreover, based on their combining ability and heterosis, yield trials can be conducted and these hybrids could be tested in multi-location trials for validation and subsequent release.

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