Forage Res., **46** (4) : pp. 320-324 (2021) **http://forageresearch.in**

ELUCIDATION OF GENE ACTION AND COMBINING ABILITY FOR FORAGE YIELD AND ITS ATTRIBUTING TRAITS IN SORGHUM [*SORGHUM BICOLOR* (L.) MOENCH]

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(Received : 9 March 2021; Accepted : 31 March 2021)

SUMMARY

The present investigation was carried out to study gene action and combining ability in sorghum [*Sorghum bicolor* (L.) Moench]. The experimental material consisted of six parents (including check GJ 43 and CSV 32F (forage)) and their 15 half-diallel crosses. The seeds of 15 F_1 hybrids were produced during summer 2019 at Sorghum Research Station, S. D. Agricultural University, Deesa, by manual emasculation and crossing. The seeds of parental lines were maintained through selfing. The analysis of variance for combining ability results revealed that mean sum of squares due to general combining ability were found highly significant for all the traits except the number of leaves per plant. In comparison, the specific combining ability effects were found significant for all the traits. Parents' gca effects explicated that the parents CSV 21F and UTFS 91 were perfect general combiner for both green fodder yield per plant and dry fodder yield per plant. The patent Malwan found perfect general combiner for plant height (cm), leaf: stem ratio and Brix value. The parent GFS 4 perfect general combiner for days to flowering, days to maturity and protein content. A perusal of data of *sca* effects implied that the cross combinations GFS 4 × UTFS 9, Malwan × GJ 43 and PSVGS 313 × UTFS 91 recorded the highest *sca* effects, which were also highest in *per se* performance which involved poor × good, poor × average, average × good parents combination, respectively.

Key words : L×T analysis, gene action, combining ability, green fodder and grain yield

Sorghum [*Sorghum bicolor* (L.) Moench] has been classified under family Poaceae, subfamily Panicoideae, tribe Andropogonae and genus Sorghum having 2n=20 chromosome number. Sorghum is often cross-pollinated crop. The centre of origin and domestication for cultivated sorghum is considered to be the northeastern part of Africa, most likely in the modern Ethiopia and Sudan regions, where cultivation started approximately 4000 - 3000 BC. Sorghum was also grown in India before recorded history and in Assyria as early as 700 BC. Sorghum is the fifth most prominent and most crucial cereal crop globally after wheat, maize, rice and barley. Sorghum is an important crop that serves as a human staple and is a primary livestock feed in intensive production systems. Sorghum may be seen as one of the crops best suited to future climate change due to its ability to adapt to conditions such as drought, salinity and high temperatures (ICRISAT, 2015). Sorghum foliage contains *dhurrin* and nitrates that are toxic at specific concentrations. Besides, sorghum contains several anti-nutritional compounds that can have serious adverse effects on human and animal nutrition. Sorghum produces the cyanogenic glycoside *dhurrin*. *Dhurrin* concentrations vary in different above-ground tissues and depending on environmental conditions. The most significant risk of stock poisoning by cyanide is from young plants or new growth, particularly in stressed or damaged plants. The risk of poisoning is low when animals feed on flowering and seeding plants or silage. Grain and sweet sorghums have higher levels of dhurrin than forage sorghums. The success of the breeding procedure is determined by the valuable gene combinations, organized in good combining lines and isolation of valuable germplasm. Some lines produce outstanding progenies on crossing with others. In contrast, others may look equally desirable but may not produce good progenies on the crossing. The lines, which perform well in combination, are eventually of great importance to the plant breeders. The combining ability helps in partitioning the total genetic variation into general combining ability of parents and specific combine ability of crosses, which helps assess the nature of gene action controlling different characters**.** Hence, the investigation of general and specific combining ability would yield beneficial information. Accordingly, a good knowledge of gene action involved in the inheritance of quantitative characters of economic importance is required to form an efficient breeding plan leading to rapid improvement.

MATERIALS AND METHODS

The present investigation was carried out to study gene action and combining ability in sorghum [*Sorghum bicolor* (L.) Moench]. The experimental material consisted of six parents (*viz,*. CSV 21F, Malwan, GFS 4, PSVGS 313, UTFS 91, including checks GJ 43 and CSV 32F (forage)) and their 15 half-diallel crosses. The seeds of 15 F_1 hybrids were generated during summer 2019 at Sorghum Research Station, S. D. Agricultural University, Deesa by manual emasculation and crossing. The seeds of parental lines were maintained through selfing. A set of 22 genotypes comprising of six parents (including check GJ 43 and CSV 32F) and their 15 F_1 hybrids were sown in Randomized Block Design (RBD) with three replications during *Kharif* 2019. Each entry sown in 1.5 m length in two rows with 45 ×10 cm spacing. The recommended agronomical practices and plant protection measures were adopted for raising a good crop. The observations were recorded on five randomly selected plants from each genotype in each replication for all the mentioned traits except days to flowering and days to maturity recorded on a plot basis. The data were recorded for all the entries in each replication. The analysis of variance was carried out as per the procedure suggested by Sukhatme and Ambe (1985). The mean value of 21 entries (parent and their F_1 hybrids) were entered in the computer and combining ability analysis was carried out according to the procedure given by Griffing (1956) as per Method II (in which parents and a set of F_1's without reciprocals are included) and Model I [which assumes that the genotypes and block effects are constant (fixed) but the environmental effect is variable].

RESULTS AND DISCUSSION

The analysis of variance for combining ability and estimates of variance components shown in Table

TABLE 1
Analysis of variance for combining ability of thirteen traits in sorghum

Sources of variation	d. f.	Days to flowering	Days to maturity	Plant height	Number of leaves/ plant	Stem girth	Leaf length	Leaf width
GCA	5	123.23**	133.87**	2216.76**	0.86	2.75**	67.39**	0.76**
SCA	14	36.60**	35.42**	1833.73**	0.74*	1.56*	35.71*	0.40**
Error	40	0.64	0.83	403.76	0.37	0.78	17.58	0.14
δ^2GCA		15.32	16.63	226.63	0.06	0.25	6.23	0.08
δ^2SCA		35.96	34.58	1429.67	0.37	0.78	18.12	0.26
δ^2GCA / δ^2SCA		0.43	0.48	0.16	0.17	0.32	0.34	0.30

TABLE 1. Conti…

Sources of variation	d. f.	Leaf : stem ratio	Grain yield/ plant	Green fodder yield/plant	Dry fodder yield/plant	Protein content	Brix value
GCA	5	0.002**	9.17**	12866.55**	1336.77**	3.18**	4.91**
SCA	14	0.001**	5.38**	6599.09**	676.86**	1.22**	2.60**
Error	40	0.000	0.56	1004.20	107.83	0.25	0.24
δ^2GCA		0.000	1.08	1482.79	153.62	0.37	0.58
δ^2SCA		0.001	4.83	5594.90	569.04	0.97	2.36
δ^2GCA / δ^2SCA		0.537	0.22	0.27	0.27	0.38	0.25

* $P \leq 0.05$, ** $P \leq 0.01$.

1. The analysis of variance for combining ability partitioning the total genetic variance into general combining ability, representing the additive type of gene action and specific combining ability as a measure of the non-additive type of gene action. The results revealed that the mean sum of squares due to general combining ability were found highly significant for all the traits except the number of leaves per plant. Whereas the specific combining ability effects were found significant for all the traits. The ratio (δ^2GCA / δ^2SCA) variance for various traits revealed the importance of the non-additive type of gene action in the expression of yield and component traits. In the present study, significant GCA and SCA variances for all the traits except the number of leaves per plant for GCA variance suggesting the importance of both additive and non-additive type of gene action in the inheritance of traits. In the number of leaves per plant, non-additive type of gene action is more important than additive type. Comparing the relative magnitude of general and specific combining ability variances implied the SCA variance was greater than GCA variance for all the traits evincing that non-additive genetic effects were played a more important role than additive effects. As observed in the present study, the predominant role of non-additive gene action in the inheritance of green fodder yield per plant, dry fodder yield per plant and contributing traits in sorghum were in correspondence with results reported by various workers in different traits *viz.* for green fodder yield per plant (g) Soujanya *et al.* (2018), Rathod *et al.* (2019), for dry fodder yield per plant (g) Vekariya *et al.* (2017) and Rathod *et al.* (2019).

The general combining ability effects of six parents for thirteen traits are depicted in table 2. The parents are classified as good, average and poor general combiner for different traits based on estimates of *gca* effect (Table 3). Parents' gca effects explicated that none of the parents consistently good general combiner for all the traits under study. The parents CSV 21F and UTFS 91 were perfect general combiner for both green fodder yield per plant and dry fodder yield per plant. The parent CSV 21F was also an excellent general combiner for plant height and leaf length. Parent UTFS 91 was also a perfect general combiner for leaf width (cm) and Brix. The patent Malwan was the perfect general combiner for plant height (cm), leaf: stem ratio and Brix value. The parent

TABLE 2

General combining ability (gca) effects for thirteen traits in sorghum

Parents	Days to flowering	Days to maturity	Plant height	Number of leaves/ plant	Stem girth	Leaf length	Leaf width
CSV 21F	4.07**	4.32**	16.85*	0.38	-0.38	3.08*	0.02
Malwan	2.32**	2.99**	24.69**	0.34	-0.42	-1.12	-0.44**
GJ 43	-0.26	-0.35	-14.75*	-0.09	-0.11	-0.95	0.10
GFS 4	-7.35**	-7.47**	-4.58	-0.38	-0.52	-4.65**	-0.26*
PSVGS 313	0.99**	0.32	-9.33	-0.35	0.94**	2.88*	0.14
UTFS 91	0.24	0.19	-12.89	0.10	0.49	0.76	0.44**
S. E. (gi) (±)	0.26	0.29	6.49	0.20	0.29	1.35	0.21

TABLE 2 Cont...

Parents	Leaf : stem ratio	Grain yield/ plant	Green fodder yield/plant	Dry fodder yield/plant	Protein content	Brix value value
CSV 21F	-0.01**	-1.12**	51.19**	16.62**	0.23	-0.53**
Malwan	0.02**	-0.60*	-42.44**	-13.50**	0.16	0.99**
GJ 43	-0.02**	1.65**	-11.55	-3.86	-1.16**	-0.89**
GFS 4	0.01	-0.54*	-42.50**	-13.71**	0.70**	0.16
PSVGS 313	0.004	0.98**	4.57	1.33	0.22	-0.55**
UTFS 91	-0.01*	-0.37	40.73**	13.12**	-0.15	0.82**
S. E. (gi) (±)	0.004	0.24	10.23	3.35	0.16	0.16

* $P \leq 0.05$, ** $P \leq 0.01$.

TABLE 3
Classification of parents based on general combining ability (gca) effects for thirteen traits in sorghum

Parents	Days to flowering	Days to maturity	Plant height	Number of leaves/plant	Stem girth	Leaf length	Leaf width
CSV 21F	P	P	G	A	A	G	A
Malwan	P	P	G*	A	A	A	P
GJ 43	A	A	P	A	A	A	A
GFS 4	G*	G*	A	A	A	P	P
PSVGS 313	P	A	A	A	P	G	A
UTFS 91	A	A	A	A	A	A	G*

TABLE 3 Cont..

Parents	Leaf : stem ratio	Grain yield/ plant	Green fodder yield/plant	Dry fodder yield/plant	Protein content	Brix value
CSV 21F	P	P	G*	G*	A	P
Malwan	G*	P	P	P	A	G*
GJ 43	P	G*	A	A	P	P
GFS 4	A	P	P	P	G*	A
PSVGS 313	A	G*	A	A	A	P
UTFS 91	P	A	G*	G*	A	G

Where : G = Good general combiner; G* = Very good combiner; A = Average general combiner; P = Poor general combiner

GFS 4 perfect general combiner for days to flowering, days to maturity and protein content.

The best three crosses selected based on *sca* effects for various traits (Table 4). The maximum and minimum range of combining ability effects is depicted in figure 1. A perusal of data implied that none of the crosses had high-ranking *sca* effects for all the traits. The data revealed that the high ranking *sca* for most of the traits were accompanied by high ranking per se performance, proving the predominant role of non-additive gene effects in the expression of green fodder yield per plant, dry fodder yield per plant and component traits. For green fodder yield per plant and dry fodder yield per plant, they seem that hybrids with high *sca* effects analogue, high heterobeltiosis in some of the yield and component traits suggested that *sca* performance might be an essential criterion for choosing the best hybrids. The crosses GFS 4 × UTFS 9, Malwan × GJ 43 and PSVGS 313 × UTFS 91 recorded the highest *sca* effects, which involved poor × good; poor × average and average × good parent combinations, respectively.

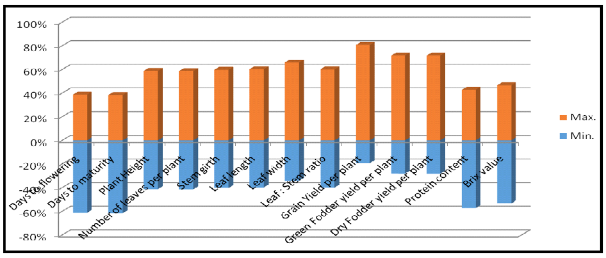

Fig. 1. The minimum and maximum range of specific combining ability (sca) effects in sorghum.

CONCLUSION

The result from the analysis of variance for combining ability revealed that the mean sum of squares due to general combining ability was found highly significant for all the traits except the number of leaves per plant. Whereas, the specific combining ability effects were found significant for all the traits. Parents' gca effects explicated that the parents CSV 21F and UTFS 91 were perfect general combiner for both green fodder yield per plant and dry fodder yield per plant. The patent Malwan was the perfect general combiner for plant height (cm), leaf: stem ratio and Brix value. The parent GFS 4 perfect general combiner for days to flowering, days to maturity and protein content. A perusal of data of *sca* effects implied that the cross combinations GFS 4 × UTFS 9, Malwan × GJ 43 and PSVGS 313 × UTFS 91 recorded the highest *sca* effects which involved poor × good, poor × average, average × good parents combination, respectively.

TABLE 4
Specific combining ability (sca) effects of F1 hybrids for thirteen traits in sorghum

S. No.	Hybrids (F_1)	Days to flowering	Days to maturity	Plant height	Number of leaves/plant	Stem girth	Leaf length	Leaf width
1.	CSV 21F × Malwan	-0.12	0.58	-20.31	-0.73	0.53	-4.57	0.05
2.	CSV 21F × GJ 43	-1.20*	-2.42**	7.47	0.51	0.07	-0.03	0.36
3.	CSV 21F × GFS 4	7.55**	7.37**	32.50*	0.86	0.79	-1.00	0.22
4.	CSV 21F × PSVGS 313	-5.45**	-3.42**	25.65	-0.03	-1.09	5.77	0.53
5.	CSV 21F × UTFS 91	1.63**	1.37*	46.28**	-0.15	-1.35*	13.00**	-0.27
6.	Malwan × GJ 43	3.55**	2.92**	36.69*	0.07	-0.12	6.62*	0.84**
7.	Malwan × GFS 4	5.63**	5.04**	1.13	-0.44	-0.02	2.80	0.49
8.	Malwan × PSVGS 313	-3.70**	-3.75**	39.54*	1.00*	-0.34	-0.88	-0.13
9.	Malwan × UTFS 91	-1.29*	-1.96**	39.50*	0.02	-0.16	-2.11	-0.11
10.	GJ 43 × GFS 4	6.55**	7.38**	-37.83*	0.39	0.64	-1.20	-0.05
11.	GJ 43× PSVGS 313	-5.79**	-5.08**	-19.01	-0.50	-1.56*	-3.53	-0.18
12.	GJ 43 × UTFS 91	-5.37**	-5.29**	-31.99*	-1.08*	-0.24	-8.59**	-0.56*
13.	GFS 4 × PSVGS 313	1.63**	2.37**	35.89*	0.58	0.88	-1.94	0.64*
14.	GFS 4 × UTFS 91	-11.95**	-11.83**	53.91**	1.53**	2.31**	3.36	1.08**
15.	PSVGS 313 × UTFS 91	6.71**	7.37**	-28.01	0.51	1.32*	-6.76*	-0.04
	S. E. (Sij) (±)	0.59	0.67	14.71	0.45	0.65	3.07	0.28
	Range	-11.95 to 7.55	-11.83 to 7.38	-37.83 to 53.91	-1.08 to 1.53	-1.56 to 2.31	-8.59 to 13.00	-0.56 to 1.08

TABLE 4. Conti..

S. No.	Hybrids (F_1)	Leaf : stem ratio	Grain yield/ plant	Green fodder yield/plant	Dry fodder yield/plant	Protein content	Brix value
1	CSV 21F × Malwan	-0.02	1.85**	-22.14	6.69	-1.69**	0.35
2	CSV 21F × GJ 43	0.01	-1.77**	-1.23	0.03	0.95*	0.63
3	CSV 21F × GFS 4	-0.02*	0.51	58.92*	19.51*	-1.28**	-1.02**
4	CSV 21F × PSVGS 313	0.01	-1.56**	11.25	3.28	0.77*	-1.31**
5	CSV 21F × UTFS 91	0.01	0.17	-48.72*	-16.34*	1.26**	-1.31**
6	Malwan × GJ 43	0.03**	-1.58**	86.13**	26.99**	0.46	2.07**
7	Malwan × GFS 4	0.06**	0.02	-32.58	-10.42	0.85*	-0.88*
8	Malwan × PSVGS 313	0.00	-0.66	-47.85*	-15.42*	1.10**	2.09**
9	Malwan × UTFS 91	0.00	0.04	-29.62	-9.22	0.49	-1.44**
10	GJ 43 × GFS 4	-0.04**	-0.11	18.13	6.03	-1.23**	-2.39**
11	GJ 43× PSVGS 313	-0.01	7.40**	-73.94**	-23.78**	-1.10**	-1.05**
12	GJ 43 × UTFS 91	-0.01	-0.25	-38.37	12.54	0.19	1.25**
13	GFS 4 × PSVGS 313	0.00	-0.68	51.01*	15.42*	0.09	1.70**
14	GFS 4 × UTFS 91	0.01	0.17	188.78**	60.52**	0.92*	0.67
15	PSVGS 313 × UTFS 91	-0.02*	-0.84	60.31*	19.57*	0.28	1.44**
	S. E. (Sij) (±)	0.008	0.55	23.19	7.60	0.36	0.36
	Range	-0.04 to 0.06	-1.77 to 7.40	-73.94 to 188.78	-23.78 to 60.52	-1.69 to 1.26	-2.39 to 2.09

* $P \leq 0.05$, ** $P \leq 0.01$.

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