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Research Article

Genetic analysis using Griffing's approach for forage yield and components in sorghum

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Abstract
The present study was carried out using seven parental lines including check CSV 46F and their 21 diallel crosses, excluding reciprocal. The experiment was evaluated in randomised block design with three replications during *Kharif* 2021 at the Centre for Millets Research, Sardarkrushinagar Dantiwada Agricultural University, Deesa. The analysis of variance (mean sum of squares) revealed significant differences for the genotypes, parents, hybrids and parents *vs.* hybrids among most of the characters, which explained a sufficient amount of heterosis and was reflected in crosses for fodder yield and its attributing characters. The parents SH 1488 and DS 200 recorded maximum mean performance for green forage yield and dry fodder yield per plant. The result of ANOVA for combining ability revealed that the mean sum of squares due to *GCA* and *SCA* were found highly significant for studied characters. The ratio ($\sigma^2_{GCA}/\ \sigma^2_{SCA}$) of variances for various characters bare standing of non-additive gene action type in the appearance of forage yield and supporting characters. The parent CSV 21F was found to be a good general combiner for green fodder yield per plant. While, parents SH 1488, DS 200 and CSV 21F were found to be good general combiners for dry fodder yield. The parent SSG 59-3 was a very good general combiner for days to flowering, total plant height, stem diameter, crude protein and HCN content. The crosses S 652 × CSV 46F, DS 200 × CSV 21F and SSG 59-3 × S 652 for green fodder yield per plant, while SSG 59-3 × S 652, DS 200 × CSV 21F and SSG 59-3 × CSV 46F for dry fodder yield per plant recorded the highest *sca* effects. Based on all the genetic parameters, the crosses SSG 59-3 × S 652, SH 1488 × S 652, SH 1488 × DSF 182 and DS 200 × CSV 21F with high mean performance, high *sca* effects and at least one parent having good to moderate *gca* effects would increase the frequency of favourable alleles. Therefore, it may be hopeful to select good homozygous lines to ameliorate respective characters in forage sorghum. It can also be used directly in varietal breeding programmes.

Keywords: Forage sorghum, Heterosis, *GCA*, *SCA* and forage yield.

INTRODUCTION

Sorghum is one of the chief cereal crops in the world. It is a vital cereal crop which aids as a human staple and is a key livestock feed in intensive production systems. In sorghum, grain and green biomass (i.e., leaves and stalks) are used for animal feed. Sorghum economically substitutes maize, since it needs less water to produce similar yields due to its adaptableness to dry conditions. Fodder sorghum cultivation practices are similar to grain sorghum, but only differed in terms of being grazing management and the harvesting of green matter for hay or silage production.

To make forage sorghum as an enterprising and remunerative crop, there is an urgent need to initiate research for the development of varieties and hybrids having faster growth, a multi-cut habit with high regeneration, early to medium maturity and higher fodder yield with suitable quality parameters like juiciness, sweetness, high protein content and minimum toxic constituents like HCN. Knowledge and information regarding crop genetic architecture (combining ability and gene action) are necessary to develop such varieties and hybrids. Moreover, in a heterosis breeding programme, it is essential to study and evaluate available useful, promising, diverse potential lines in their hybrid combinations for yield and attributing characters.

The concept of heterosis proved as the fundamental genetic approach to improving yield and components in crop plants. The prime objective of heterosis breeding is to identify the specific cross capable of attributing the maximum heterotic effect in the F_1 generation. Combining ability analysis is essential to victimise both good and poor combiners and helps identify an appropriate parental genotype. It also elucidates the basis of gene action involved in a particular trait inheritance.

MATERIALS AND METHODS

The genetic material comprised seven parental genotypes *viz*., SSG 59-3, SH 1488, S 652, DS 200, CSV 21F, DSF 182, CSV 46F (check) and 21 diallele crosses excluding reciprocals. The seeds of 21 F_1 crosses were generated during the summer, 2021 at the Centre for Millets Research, Sardarkrushinagar Dantiwada Agricultural University, Deesa, by hand emasculation and pollination technique. A set of 28 genotypes, including seven parents (with check CSV 46F) and their 21 F_1 hybrids, were sown in Randomized Block Design (RBD) in three replications during *Kharif,* 2021. Each genotype was sown in two rows of 2.0 m length with 30 cm inter-row spacing. The observations were recorded both on visual basis for days to flowering, while extent on five randomly selected and tagged plants of each genotype in each replication for total plant height (cm), the number of leaf per plant, stem diameter (mm), leaf length of the blade (cm), leaf width of the blade (cm), leaf: stem ratio, green fodder yield per plant (g), dry fodder yield per plant (g), crude protein content (%), brix content (%) and HCN content (ppm). The replications-wise mean values of each genotype for twelve characters were subjected to statistical analysis as per the Randomised Block Design (RBD) procedure suggested by Panse and Sukhatme (1985). The analysis of variance (ANOVA) was carried out as per the method suggested by Snedecor and Cochran (1967) and reviewed by Panse and Sukhatme (1985). Heterosis was estimated as per cent increase or decrease in the mean value of F_1 hybrid over the better parent, *i.e.,* heterobeltiosis (Fonseca and Patterson, 1968) and over standard check *i.e.,* standard heterosis Meredith and Bridge (1972) for each character. Classified the heterosis level, *i.e*., low, moderate and high (Joshi *et al.,* 2021). The mean value of 28 genotypes (seven parents and their twenty-one F_1 hybrids) were subjected to combining ability analysis was carried out according to the procedure given by Griffing (1956) as per Method- II and Model- I.

Table 1. ANOVA for experimental design of twelve characters in forage sorghum

Variation Source	d.f.	Days to flowering	Total plant height	Number of leaf per plant	Stem diameter	Leaf length of blade	Leaf width of blade
Replications	2	4.96	906.38	2.56	6.16	32.67	0.80
Genotypes (G)	27	23.95**	3568.59**	4.07**	14.86**	75.26**	1.71**
Parents (P)	6	31.41**	6213.20**	0.97	33.92**	120.49**	2.78**
Hybrids (H)	20	22.87**	2784.31**	5.13**	8.63**	63.49**	1.35**
Parents *vs.* Hybrids	1	0.89	3386.53**	1.49	25.22**	39.35	2.38*
Error	54	4.14	346.13	1.21	2.20	24.98	0.36

Table 1. Continued

Variation Source	d.f.	Leaf: stem Ratio	Green fodder yield per plant	Dry fodder yield per plant	Crudes protein content	Brix content	HCN content
Replications	2	0.001	5472.42	1049.65	1.70	2.93	26.06
Genotypes (G)	27	0.004**	17525.00**	3465.26**	12.56**	14.25**	1902.60**
Parents (P)	6	0.003**	13830.14**	4642.19**	7.91**	29.18**	1844.49**
Hybrids (H)	20	0.004**	15124.01**	2193.27**	14.54**	10.39**	2008.71**
Parents *vs.* Hybrids	1	0.001	87713.95**	21843.49**	1.01	1.82	129.10*
Error	54	0.000	2090.34	467.00	0.69	0.96	21.55

* P $\leq$ 0.05 (5%); ** P $\leq$ 0.01 (1%)

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RESULTS AND DISCUSSION

The ANOVA for all the studied characters is depicted in **Table 1**. The results showed significant differences due to genotypes for all the characters. This supports those parents and their hybrids under study possessed appropriately more extant genetic variability. The significant differences among parents showed greater diversity in the parental lines. In the case of hybrids, significant differences were noted for studied the characters that specify varying performance of cross combinations. MSS due to parents *vs.* hybrids were found significant for six characters *viz.,* total plant height, stem diameter, leaf width of blade, green fodder yield per plant, dry fodder yield per plant and HCN content which explained the sufficient amount of heterosis was reflected in crosses for some of the yield supporting characters.

Considering the primary breeding objectives, *i.e.,* high yield, earliness and quality parameters, the *per se* concert of parents indicated that the parent SSG 59-3 showed better mean performance for days to flowering, total plant height (cm), stem diameter (mm) and crude protein content (%). While the parent SH 1488 was found superior for green fodder yield per plant (g) and minimum HCN content (ppm). The genotype DS 200 was found ideal for leaf width of blade (cm) and dry fodder yield per plant (g). The parental genotype DSF 182 was rewarded higher for leaf length of blade (cm) and leaf stem ratio. The mean performance of parents revealed that the parents, S 652 and CSV 46F was top ranking for the number of leaf per plant and Brix content (%), respectively.

The F_1 hybrid SH 1488 × DSF 182 showed better mean performance for the number of leaf per plant and the width of blade (cm). The crosses S 652 × CSV 46F and DS 200 × CSV 21F recorded maximum green fodder yield (g) and dry fodder yield per plant (g), respectively. The common top ranking F_1 hybrids for green fodder and dry fodder yield per plant were DS 200 × CSV 21F and SSG 59-3 × S 652. The cross S 652 × DS 200 was higher for leaf: stem ratio and minimum stem diameter (mm). While it was poor in green fodder yield per plant revealed that the characters leaf: stem ratio and desirable minimum stem diameter against the yield parameter. The cross combination SSG 59-3 × DS 200 and SSG 59-3 × CSV 46F showed minimum days to flowering and HCN content (ppm), respectively. Whereas the crosses SSG 59-3 × S 652, SSG 59-3 × CSV 21F, SH 1488 × S 652 and DSF 182 × CSV 46F exhibited their superiority for total plant height (cm), brix content (%), crude protein content (%) and leaf length of the blade (cm), respectively. The correspondence range of yield and attributes were also reported earlier by Patel *et al.* (2018[b]), Patel *et al.* (2020), Rathod *et al.* (2020) and Joshi *et al.* (2021). However, the range may vary as it merely depends on genotype potential and environmental fluctuation.

Considering the importance of fodder yield in the present investigation, out of 21 F_1 hybrids, four and nine hybrids manifested significant and positive estimates of heterobeltiosis and standard heterosis over the check CSV 46F (**Table 2**), respectively. For green fodder yield per plant a wide range of heterosis over better parent and standard checks were recorded i.e. -30.84 (S 652 × DS 200) to 86.40 per cent (S 652 × CSV 46F) heterobeltiosis, -17.22 (S 652 × DS 200) to 86.40 per cent (S 652 × CSV 46F) over CSV 46F. The hybrids S 652 × CSV 46F (86.40 & 86.40%), SSG 59-3 × S 652 (55.03 & 51.41%) and DS 200 × CSV 21F (43.81 & 73.65%) evinced significant and positive heterosis over better parent and standard check CSV 46F. The low to high estimates of heterobeltiosis and standard heterosis for green fodder yield per plant were also reported earlier by Prakash *et al.* (2010), Pandey and Shrotria (2012), Naik *et al.* (2018), Soujanya *et al.* (2018), Patel *et al.* (2018a), Patel *et al.* (2018b), Rathod *et al.* (2020) and Patel *et al.* (2020).

Table 2. Heterotic effects of forage sorghum traits (in per cent)

Characters	Over better parent				Over standard check (CSV 46F)			
	+ve	-ve	Total	Range	+ve	-ve	Total	Range
Days to flowering	07	00	07	-4.05 to 10.99	00	16	16	-14.48 to -1.82
Total plant height	01	05	06	-25.26 to 13.93	17	00	17	-1.01 to 66.46
Number of leaf per plant	03	01	04	-21.46 to 22.19	04	00	04	-18.75 to 25.73
Stem diameter	12	00	12	-10.14 to 88.05	00	07	07	-30.23 to 11.32
Leaf length of blade	00	03	03	-19.50 to 9.96	06	00	06	-5.18 to 22.34
Leaf width of blade	02	04	06	-19.58 to 20.55	02	01	03	-17.76 to 27.57
Leaf: stem ratio	02	11	13	-43.23 to 31.19	04	03	07	-34.73 to 58.68
Green fodder yield per plant	04	01	05	-30.84 to 86.40	09	00	09	-17.22 to 86.40
Dry fodder yield per plant	07	02	09	-34.36 to 82.17	07	00	07	-20.58 to 61.99
Crude protein content	03	04	07	-52.60 to 40.33	04	04	08	-52.60 to 40.63
Brix content	01	16	17	-35.99 to 69.47	00	19	19	-44.10 to 4.16
HCN content	11	06	17	-80.72 to 458.78	11	01	12	-50.16 to 444.40

In the case of dry fodder yield per plant, out of the total studied hybrids, seven hybrids registered significant and positive heterosis over better parent and standard check CSV 46F. A wide spectrum of heterosis over better parent and the standard check was recorded i.e. -34.36(S 652 × DS 200) to 82.17 (SSG 59-3 × S 652) per cent over better parent and -20.58 (S 652 × DS 200) to 61.99 (DS 200 × CSV 21F) per cent over the standard check CSV 46F. The hybrids SSG 59-3 × S 652 (82.17 & 39.58%), DS 200 × CSV 21F (33.89 & 61.99%) and CSV 21F × DSF 182 (56.56 & 29.42%) exhibited significant and desirable heterosis over better parent and standard check CSV 46F (**Table 3a**) A wide range of heterosis for dry fodder yield in sorghum also reported earlier by Prakash *et al.* (2010), Pandey and Shrotia (2012), More *et al.* (2016), Naik *et al.* (2018), Soujanya *et al.* (2018), Patel *et al.* (2018[a]), Patel *et al.* (2018[b]), Patel *et al.* (2020), Rathod *et al.* (2020) and Joshi *et al*. (2021).

Based on a comparative study of best heterotic hybrids, for green fodder yield per plant and dry fodder yield per plant over both better parent and standard check, it revealed that these hybrids also expressed significant and positive heterosis over better parent and/or standard check for various component characters *viz.,* days to flowering, total plant height, the number of leaf per plant, stem diameter, leaf: stem ratio, green fodder yield per plant, dry fodder yield per plant, crude protein content and HCN content (**Table 3b and 3c**).

The ANOVA for combining ability for twelve characters is furnished in **Table 4**. The results showed that MSS due to *GCA* and *SCA* were found to be extremely important for all studied characters *viz.,* days to flowering, total plant height, the number of leaf per plant, stem diameter, leaf length of blade, leaf width of blade, leaf: stem ratio, green fodder yield per plant, dry fodder yield per plant, crude protein content, brix content and HCN content indicating both additive and non-additive gene actions were necessary for inheritance of these characters. The status of non-additive gene action in the expression of forage yield and supporting characters were also proved based on the ratio of $\sigma^2_{GCA}/\sigma^2_{SCA}$ for studied characters in forage sorghum. The predominant role of non-additive gene action in the inheritance of green fodder yield per plant, dry fodder yield per plant and contributing characters in sorghum was following the results reported by various workers in different characters *viz.,* for green fodder yield per plant [Padmashree *et al*., (2014), Dehinwal *et al*., (2017), Vekariya *et al*., (2017), Chaudhari *et al*., (2017), Patel *et al.,* (2018c), Kumari *et al*., (2018), Rathod *et al.,* (2019), Parmar *et al.,* (2019) and Patel *et al.,* (2021)], for dry fodder yield per plant [Padmashree *et al.,* (2014), Kumar and Chand, (2015), Chaudhary *et al.,* (2017), Dehinwal *et al.,* (2017), Jadhav and Deshmukh, (2017), Patel *et al.,* (2018c), Rathod *et al.,* (2019), Parmar *et al.,* (2019), Patel *et al.,* (2021) and Joshi *et al.,*(2022)].

Table 3a. Heterotic crosses in sorghum for green and dry fodder yield per plant with other components

S. No.	Hybrids	Per cent heterosis over		Desired and significant heterobeltiosis/ standard heterosis for components
		Better parent	Standard Check (CSV 46F)	
Green fodder yield per plant with attributes				
1	S 652 × CSV 46F	86.40** (523.89)	86.40**	DF, SD
2	SSG 59-3 × S 652	55.03** (425.54)	51.41**	DF, PH, NOL, DFY, CPC
3	DS 200 × CSV 21F	43.41** (488.07)	73.65**	PH, SD, DFY, CPC, HCN
Dry fodder yield per plant with attributes				
1	SSG 59-3 × S 652	82.17** (185.50)	39.58**	DF, PH, NOL, GFY, CPC
2	CSV 21F × DSF 182	56.56** (172.00)	29.42*	DF, PH, NOL, SD, LSR, CPC
3	DS 200 × CSV 21F	33.89** (215.28)	61.99**	PH, SD, GFY, CPC, HCN

* $P \leq 0.05$ (5%); ** $P \leq 0.01$ (1%).

Figure in the parentheses indicated mean performance (g/plant)

Where,
DF: Days to flowering
PH: Total plant height
NOL: Number of leaf per plant
SD: Stem diameter
LSR: Leaf: stem ratio
GFY: Green fodder yield per plant
DFY: Dry fodder yield per plant
CPC: Crude protein content
HCN: HCN content

Table 3b. The overall picture of heterosis level in promising heterotic crosses of forage sorghum for yield (*i.e.*, green & dry fodder) and its attributes with better parent

S. No.	Hybrids	DF	PH	NOL	SD	LLB	LWB	LSR	GFY	DFY	CPC	BC	HCN
1	S 652 × CSV 46F	Low	Low	Low	Moderate	Low	Low	Low	High	Low	Low	Low	High
2	SSG 59-3 × S 652	Low	Moderate	Moderate	High	Low	Moderate	Low	High	High	Low	Low	High
3	DS 200 × CSV 21F	Low	Low	Low	Low	Low	Low	Low	Moderate	Moderate	Moderate	Low	Low
4	SSG 59-3 × S 652	Moderate	Moderate	Moderate	High	Low	Moderate	Low	High	High	Moderate	Low	High
5	CSV 21F × DSF 182	Low	Low	Moderate	Moderate	Low	Low	Low	Low	High	Moderate	Low	High
6	DS 200 × CSV 21F	Moderate	Low	Moderate	Low	Low	Low	Low	High	Moderate	Moderate	Low	Low

Table 3c. The overall picture of heterosis level in promising heterotic crosses of forage sorghum for yield (*i.e.*, green & dry fodder) and its attributes with standard check(CSV 46F)

S. No.	Hybrids	DF	PH	NOL	SD	LLB	LWB	LSR	GFY	DFY	CPC	BC	HCN
1	S 652 × CSV 46F	Low	Low	Low	Low	Low	Low	Low	High	Low	Low	Low	High
2	SSG 59-3 × S 652	Low	High	Moderate	Low	Low	Low	Low	Moderate	Moderate	Moderate	Low	High
3	DS 200 × CSV 21F	Low	Moderate	Low	Low	Low	Low	Low	High	High	Low	Low	Low
4	SSG 59-3 × S 652	Low	High	Moderate	Low	Low	Low	Low	High	High	Moderate	Low	High
5	CSV 21F × DSF 182	Low	High	Moderate	Low	Moderate	Moderate	High	Moderate	Moderate	Low	Low	High
6	DS 200 × CSV 21F	Low	Moderate	Low	Low	Moderate	Low	Low	High	High	Low	Low	Low

Where,

DF: Days to flowering
PH: Total plant height
NOL: Number of leaf per plant
SD: Stem diameter
LLB: Leaf length of blade
LWB: Leaf width of blade
LSR: Leaf: stem ratio
GFY: Green fodder yield per plant
DFY: Dry fodder yield per plant
CPC: Crude protein content
BC: Brix content
HCN: HCN content

Table 4. ANOVA components (MSS) for combining ability of twelve characters in forage sorghum

Source	d.f.	Days to flowering	Total plant height	Number of leaf per plant	Stem diameter	Leaf length of blade	Leaf width of blade
GCA	6	15.92**	3215.25**	1.44**	6.87**	33.87**	1.40**
SCA	20	6.00**	641.29**	1.40**	4.63**	23.71**	0.35**
Error	54	1.16	230.12	0.03	1.26	4.46	0.10
σ^2_{GCA}		1.64	331.68	0.16	0.62	3.27	0.14
σ^2_{SCA}		4.84	411.17	1.36	3.37	19.24	0.25
$\sigma^2_{GCA}/\sigma^2_{SCA}$		0.34	0.81	0.12	0.19	0.17	0.59

Table 4. conti…

Source	d.f.	Leaf: stem ratio	Green fodder yield per plant	Dry fodder yield per plant	Crude protein content	Brix content	HCN content
GCA	6	0.002**	4448.02**	1195.21**	9.35	5.07**	1179.14**
SCA	20	0.001**	6551.84**	1200.81**	2.85	4.89**	502.43**
Error	54	0.000	512.23	171.93	0.29	1.08	68.31
σ^2_{GCA}		0.000	437.31	113.70	1.01	0.44	123.43
σ^2_{SCA}		0.001	6039.62	1028.87	2.55	3.81	434.11
$\sigma^2_{GCA}/\sigma^2_{SCA}$		0.28	0.072	0.11	0.39	0.12	0.28

The top three cross combinations chosen based on *sca* effects for the characters studied are depicted in **Table 5**. The data revealed that the top ranking *sca* for most of the characters where convoyed by top ranking *per se* performance, which proves the predominant role of non-additive gene effects in the expression of green forage, dry fodder yield per plant and supporting characters. The crosses S 652 × CSV 46F, DS 200 × CSV 21F and SSG 59-3 × S 652 for green fodder yield per plant, while SSG 59-3 × S 652, DS 200 × CSV 21F and SSG 59-3 × CSV 46F for dry fodder yield per plant recorded the highest *sca* effects which involved average × average; average × good; poor × average for green fodder yield per plant and poor × average; good × good; poor × average for dry fodder yield per plant parent combinations, respectively. Furthermore, these crosses also exhibited a positive significant *sca* effect for other contributing characters *viz*., total plant height, the number of leaf per plant, stem diameter, leaf width of blade, crude protein content and HCN content.

The cross combination DS 200 × CSV 21F involving both parents having high *gca* effects for dry fodder yield and one parent having average and one parent with high *gca* effects for green fodder yield was found promising, while the cross SSG 59-3 × S 652 for total plant height, SH 1488 × DSF 182 for the number of leaf per plant, SH 1488 × CSV 21F for leaf width of blade and SH 1488 × S 652 for crude protein content involving both parents having high *gca* effects are hopeful for selecting of good homozygous lines for the amelioration of respective characters in forage sorghum and it can also use directly in a varietal breeding programme.

An examination of *per se* performance of parents and their F_1 hybrids for different characters evinced that SH 1488 and DS 200 among parents, while S 652 × CSV 46F and DS 200 × CSV 21F among hybrids was recorded as maximum mean performance for green fodder yield and dry fodder yield per plant, respectively. The common top ranking F_1 hybrids for green fodder yield per plant and dry fodder yield per plant were DS 200 × CSV 21F and SSG 59-3 × S 652. On the basis of all the genetic parameters, the crosses SSG 59-3 × S 652, SH 1488 × S 652, SH 1488 × DSF 182 and DS 200 × CSV 21F with high mean performance, high *sca* effects and at least one parent having good to moderate *gca* effects would surge the occurrence of favourable alleles.

Table 5. The top three ranking parents based on mean performance; gca effects; F1 hybrids concerning mean performance and sca effects; heterosis over better parent and standard check CSV 46F

Characters	Best performing parents	Best general combiners	Best performing hybrids	Hybrid with high *sca* effect	*gca* of parents	*sca* effects	Per cent heterosis over Better parent	Per cent heterosis over Standard check
Days to flowering	SSG 59-3 (63.67)	SSG 59-3	SSG 59-3 × DS 200 (63.00)	SSG 59-3 × DS 200	G × A	-3.81**	-1.05	-14.48**
	SH 1488 (66.00)	SH 1488	SH 1488 × DS 200 (63.33)	SH 1488 × DS 200	G × A	-3.69**	-4.05	-14.04**
	S 652 (68.33)	-	SH 1488 × S 652 (65.00)	DSF 182 × CSV 46F	A × P	-3.06**	-0.97	-8.14**
	DSF 182 (68.33)	-	-	-	-	-	-	-
Total plant height (cm)	SSG 59-3 (307.14)	SSG 59-3	SSG 59-3 × S 652 (337.56)	SSG 59-3 × DS 200	G × P	38.92**	-3.75	45.78**
	CSV 21F (270.29)	S 652	SSG 59-3 × SH 1488 (299.10)	SSG 59-3 × S 652	G × G	37.95**	9.90*	66.46**
	SH 1488 (268.61)	-	S 652 × CSV 21F (297.43)	DSF 182 × CSV 46F	A × P	34.90**	8.09	38.21**
Number of leaf per plant	S 652 (10.53)	SH 1488	SH 1488 × DSF 182 (12.07)	SSG 59-3 × S 652	P × A	2.39**	13.30	24.27*
	SH 1488 (10.27)	DSF 182	SSG 59-3 × S 652 (11.93)	SH 1488 × DSF 182	G × G	1.35**	17.53*	25.73**
	DSF 182 (9.60)	CSV 21F	CSV 21F × DSF 182 (11.73)	SSG 59-3 × SH 1488	P × G	1.27**	9.74	17.40
	CSV 46F (9.60)	-	-	-	-	-	-	-
Stem diameter (mm)	SSG 59-3 (8.70)	SSG 59-3	S 652 × DS 200 (11.77)	S 652 × DS 200	G × A	-2.51**	1.03	-30.23**
	S 652 (11.65)	S 652	S 652 × DSF 182 (12.73)	S 652 × CSV 46F	G × P	-1.99*	10.30	-23.83**
	CSV 21F (13.07)	-	S 652 × CSV 46F (12.85)	DS 200 × CSV 21F	A × A	-1.83*	3.29	-19.98**
Leaf length of blade (cm)	DSF 182 (83.04)	DSF 182	DSF 182 × CSV 46F (86.25)	DSF 182 × CSV 46F	G × A	7.33**	3.87	22.34**
	SH 1488 (81.98)	SSG 59-3	SSG 59-3 × DSF 182 (85.31)	SH 1488 × S 652	A × P	5.66**	-0.40	15.82**
	SSG 59-3 (79.77)	-	SH 1488 × DSF 182 (82.72)	S 652 × DS 200	P × P	4.41**	2.39	9.93
Leaf width of blade (cm)	DS 200 (7.71)	SH 1488	SH 1488 × DSF 182 (8.33)	SSG 59-3 × CSV 46F	P × A	1.16**	12.25	12.25
	SH 1488 (6.91)	CSV 21F	SH 1488 × CSV 21F (8.26)	SH 1488 × DSF 182	G × A	0.93**	20.55**	27.57**
	CSV 21F (6.85)	-	SSG 59-3 × CSV 46F (7.33)	SH 1488 × CSV 21F	G × G	0.79**	19.54**	26.49**
Leaf: stem ratio	DSF 182 (0.230)	DSF 182	S 652 × DS 200 (0.265)	S 652 × DS 200	G × P	0.08**	31.19**	58.68**
	S 652 (0.202)	S 652	S 652 × DSF 182 (0.240)	CSV 21F × DSF 182	A ×G	0.04**	3.48	42.51**
	CSV 21F (0.192)	-	CSV 21F × DSF 182 (0.238)	SH 1488 × DS 200	A × P	0.03**	20.73*	18.56*
Green fodder yield per plant (g)	SH 1488 (350.52)	CSV 21F	S 652 × CSV 46F (523.89)	S 652 × CSV 46F	A × A	172.88**	86.40**	86.40**
	CSV 21F (339.38)	-	DS 200 × CSV 21F (488.07)	DS 200 × CSV 21F	A × G	112.50**	43.81**	73.65**
	DS 200 (336.38)	-	SSG 59-3 × S 652 (425.54)	SSG 59-3 × S 652	P × A	106.11**	55.03**	51.41**
Dry fodder yield per plant (g)	DS 200 (160.79)	SH 1488	DS 200 × CSV 21F (215.28)	SSG 59-3 × S 652	P × A	61.27**	82.17**	39.58**
	SH 1488 (160.58)	DS 200	SSG 59-3 × S 652 (185.50)	DS 200 × CSV 21F	G × G	52.35**	33.89**	61.99**
	CSV 46F (132.90)	CSV 21F	SH 1488 × S 652 (184.27)	SSG 59-3 × CSV 46F	P × A	40.09**	31.78*	31.78*
Crude protein content (%)	SSG 59-3 (11.42)	SSG 59-3	SH 1488 × S 652 (13.50)	SH 1488 × S 652	G × G	3.60**	40.33**	40.63**
	S 652 (9.62)	SH 1488	SSG 59-3 × S 652 (12.21)	DS 200 × CSV 21F	A × P	2.42**	25.87**	1.35
	CSV 46F (9.60)	S 652	SSG 59-3 × DSF 182 (11.15)	CSV 21F × DSF 182	P × P	2.16**	22.75*	-5.00
Brix Content (%)	CSV 46F (14.92)	CSV 46F	SSG 59-3 × CSV 21F (15.54)	SSG 59-3 × CSV 21F	P × A	5.96**	69.47**	4.16
	SH 1488 (14.23)	-	SH 1488 × S 652 (14.55)	SH 1488 × S 652	A × A	3.04**	2.25	-2.48
	DSF 182 (13.23)	-	DS 200 × CSV 46F (13.13)	-	-	-	-	-
HCN content (ppm)	SH 1488 (14.46)	SSG 59-3	SSG 59-3 × CSV 46F (7.61)	DS 200 × CSV 21F	P × A	-47.37**	-80.72**	-41.45
	CSV 46F (15.27)	CSV 46F	DS 200 × CSV 21F (8.94)	S 652 × DS 200	G × P	-30.41**	-34.44*	-1.77
	SSG 59-3 (17.77)	S 652	SSG 59-3 × DSF 182 (9.00)	S 652 × DSF 182	G × P	-22.41**	-59.77**	-39.42

The figure in parenthesis indicates the mean data. * $P \leq 0.05$ (5%); ** $P \leq 0.01$ (1%).

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