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Variation in Morphological and Biochemical Characters of Various Forage Sorghum Genotypes (*Sorghum bicolor* L. Moench)

Pinki* and S.S. Siwach

College of Agriculture, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar-125004, Haryana, India

**Corresponding author*

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A B S T R A C T

The present study was conducted on 25 sorghum genotypes grown in Randomized Block Design during Kharif 2015 to evaluate, categorize and classify them for fodder yield and quality traits. Observations were recorded on eighteen variables involving morphological, quality. Wide range of variation, high coefficient of variation, were recorded for number of leaves per plant, green fodder yield, dry fodder yield and DDM, therefore it revealed the possibility of their further improvement. The mean squares due to genotypes were recorded highly significant for all the 18 characters studied. This indicated the presence of considerable genotypic variation in material among genotypes for further selection and improvement.

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench] is one of the five top cereal crops in the world. Sorghum was also grown in India and Assyria as early as 700 BC. Sorghum has a significant role in livestock production, particularly in tropical zone where feed stuffs could not meet animal requirements due to many factors such as poor soil fertility and drought (Pholsen and Suksri, 2007).

Although India is the highest milk producer country yet per capita milk production is very low due to the huge deficit in the availability of feed stuffs. This is also to note that area under forage production has not increased considerably in the last few decades and our natural grazing lands and pastures are fast degrading and decreasing. Hence, efforts should be directed to intensify forage production per unit area per unit time, which can be achieved through improved high yielding varieties and better management practices.

The greater utilization of the genetic diversity in developing sustainable solutions to basic crop constraints or enhancing the productivity will be critical in future. However, for effective utilization of the germplasm collections it is necessary to evaluate and characterize them (Reddy *et al.*, 2006). Therefore, the present investigation was undertaken in forage sorghum with the objective to assess genetic diversity in

sorghum accessions on the basis of fodder yield and quality.

Materials and Methods

Twenty five forage sorghum genotypes Bmr-1, Bmr-2, Bmr-3, Bmr-4, Bmr-5, COFS 29, HJ 513, HC 260, IS 2205, IS 2389, DUGGI, CSV 21F, S 490, S 437, S 651, G 46, SSG 59-3, HC 136, HC 171, HJ 541, PC 5, PC 7, PC 8, ICSV 700, HC 308 were used in present study.

The material was collected from Forage Section, Department of Genetics and Plant Breeding CCSHAU, Hisar and sowing was done on July 4, 2015.

The field experiment was conducted at Research Area of Forage Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar.

Observations were recorded on 31 quantitative variables. The data for different characters were statistically analysed as described by Panse and Sukhatme (1967).

Results and Discussion

The mean performance and range of different genotypes for different traits have been presented in Table 2a and b brief description of the result is given here under:

Natural height of plant up to the base of flag leaf

The range for plant height varied from 88.0-233.3 cm.

Genotype CSV 21F (233.3 cm) showed significantly higher mean followed by SSG 59-3 (211.4), S 651 (208.8) and S 490 (207.1).

Number of tillers/plant

Genotype COFS 29 (5.8) had maximum no. of tillers and HC 171 (1.0) had minimum.

Number of leaves/plant

The number of leaves/plant ranged from 10.6-30.4. Genotype PC 5 (30.4) had maximum number of leaves/plant followed by HC 308 (25.4).

Stem girth (mm)

Genotype S 490 (12.3 mm), HJ 513(12 mm) showed significant higher stem diameter than over all mean (8.7 mm). Minimum stem diameter was recorded for genotype COFS 29 (5.8 mm) while maximum stem diameter was recorded for genotype S 490 (12.3 mm).

Anther length (mm)

Maximum anther length (3.3 mm) was observed in genotype SSG 59-3 and minimum (2.0 mm) in S 651, BMR-5 and COFS29.

Stigma length (mm)

Maximum stigma length was 2.5 mm which was recorded in genotype CSV 21F followed by G 46 against a minimum of 1.0 mm was recorded in Duggi.

Time of panicle emergence (no. of days)

For this trait, genotypes COFS 29 (105 days) and BMR-1 and BMR-4 showed significantly higher than over all mean (79.4 days).

Green fodder yield/plant

Highest green fodder yield/plant was recorded from CSV 21F (266.6 gm) followed by S 490 (256.5 gm) whereas, minimum from HC 171 (77.7 gm) and overall mean was 161.1 gm.

Dry fodder yield/plant

Maximum dry fodder yield/plant 93.3 gm was recorded from genotype CSV 21F while, minimum from HC171 (27.3 gm) with mean 53.6 gm.

Neck of panicle visible above sheath

For this trait genotypes, SSG 59-3 (20.6 cm), HJ 541 (19.0 cm), HJ 513 (17.6 cm) and G 46 (18.0 cm) were observed to have high neck of panicle visible above sheath.

The range varied from 3.5 cm in duggi to 20.6 cm in SSG 59-3.

Panicle length of branches

For this trait genotypes ICSV 700 (14.0 cm), HJ 541 (13.3 cm), SSG 59-3 (13.0 cm), S 437 (12.3 cm), showed significantly higher mean.

The range was varied from 4.1cm (BMR-3) to 14.0 cm (ICSV 700).

Lignin (%)

The minimum lignin was 2.6 % observed in BMR-3 and maximum 5.8 % in IS 2389 with mean 3.9%.

***In vitro* Dry Matter Digestibility (IVDMD %)**

The IVDMD of different genotypes varied from 59.4% (PC 8) to 68.2 % (BMR-3) with mean 63%.

Crude protein (%)

The crude protein was maximum in BMR-2, ICSV700 and HC 171 (9.3 %) and minimum in BMR-5 (8.2%). The overall mean was 8.9%.

Neutral detergent fiber (NDF %)

It varied from 61.2 % (PC 7) to 75.9 % (BMR-4) with overall mean 68%.

Acid detergent fiber (ADF %)

The range for ADF was 36.1 % (BMR-1) to 56.3 % (COFS 29) with mean 43.6%.

Digestible dry matter (DDM q/ha)

DDM varied from 26.6 q/ha (HC 171) to 94.4 q/ha (CSV 21F) with mean 52.7 q/ha.

Protein yield (q/ha)

Protein yield varied from 3.7 q/ha (HC 171) to 13.0 q/ha (CSV 21F) with mean 7.4 q/ha. The mean squares were observed to be highly significant for all the 18 characters studied (Table 3a and b). This indicated prevalence of enough genetic variability in the material under study for selection and improvement of genotypes. This also indicated its suitability for further statistical analysis for all the character studied.

In order to get enhanced performance of animals, the quality of fodder being fed to them is of utmost importance. The main quality attributes in forage sorghum are protein, IVDMD, NDF, ADF. Out of these protein, IVDMD are most important.

Like other straws, the nutritive value of sorghum fodder is also low due to presence of high content of above mentioned cell wall constituents as well as lignin and low content of protein and minerals. Crude protein (CP) content is often considered as a good determinant of quality. Crude protein is commonly used measure of feed quality. Good quality forage generally will have higher protein content.

The major goal in breeding programme is to improve crude protein more than 9 %. IVDMD (*in vitro* dry matter digestibility) is a measure of plant quality index (Kumar and Shib, 2003) (Table 1).

Table.1 Morphological characters as per DUS parameters

	Parameters	States	Stage of observation
1.1	Seedling : Anthocyanin colouration of coleoptiles	Yellow green Greyed purple	Seedling 7-8 days after sowing
1.2	Leaf sheath : Anthocyanin colouration	Yellow green Greyed purple	5th leaf
1.3	Leaf : Midrib colour (5th fully developed leaf)	White Yellow green Greyed yellow Greyed purple	5th leaf
1.4	Plant : Time of panicle emergence (50% of the plants with 50% anthesis)	Very early (<56 days) Early (56-65 days) Medium (66-75 days) Late (76-85 days) Very late (>85 days)	Panicle emergence
1.5	Plant : Natural height of plant upto base of flag leaf	Very short (<76 cm) Short (76-150 cm) Medium (151-225 cm) Tall (226-300 cm) Very tall (>300 cm)	Panicle emergence
1.6	Flag leaf : Yellow colouration of midrib	Absent Present	Panicle emergence
1.7	Lemma : Arista formation	Absent Present	Flowering
1.8	Stigma : Anthocyanin colouration	Absent Present	Upper portion of the panicle at the end of flowering
1.9	Stigma : Yellow colouration	Absent Present	Flowering
1.10	Stigma : Length	Short (<1mm) Medium (1-2mm) Long (>2mm)	Flowering
1.11	Flower with pedicel : Length of flower	Very short Short Medium Long Very long	Flowering
1.12	Anther : Length	Short (<3mm) Medium (3-4mm) Long (>4mm)	Flowering
1.13	Anther : Colour of dry anther	Yellow orange Orange Orange red Grayed orange	End of flowering Flowering
1.14	Number of leaves per plant	Less (<15) Medium (15-40) More (>40)	Physiological maturity
1.15	Stem girth (cm)	Small (<2 cm) Medium (2 – 4 cm) Large (> 4 cm)	Physiological maturity
1.16	Number of tillers per plant	Less (< 2) Medium (2-5) More (> 5)	Physiological maturity
1.17	Panicle : Length of branches (middle third of panicle)	Short (<5.1 cm) Medium (5.1-10 cm) Long (10.1-15 cm) Very long (>15 cm)	Physiological maturity

1.18	Panicle : Density at maturity (ear head compactness)	Very loose Loose Semi loose Semi compact Compact	Physiological maturity
1.19	Panicle : Shape	Reversed pyramid Panicle broader in upper part Symmetric Panicle broader in lower part Pyramidal	Physiological maturity
1.20	Neck of panicle : Visible length above sheath	Absent or very short (<5.1 cm) Short (5.1-10 cm) Medium (10.1-15 cm) Long (15.1-20 cm) very long (>20cm)	Physiological maturity
1.21	Glume : Length	Very short (25% of grain covered) Short (50% of grain covered) Medium (75% of grain covered) Long (100% of grain covered) Very long (longer than the grain)	Physiological maturity
1.22	Grain : Threshability	Freely threshable (<11% unthreshed grain) Partly thresahble (11 – 50% unthreshed grain) Difficult to thresh (>50% unthreshed grain)	Maturity
1.23	Caryopsis : Colour after threshing	White RHS 155 Greyed white RHS 156 Yellow white RHS 158 Yellow orange RHS 14-20 Greyed orange RHS 200	After threshing
1.24	Grain : Shape (in dorsal view)	Narrow elliptic Elliptic Circular	After threshing
1.25	Grain : Shape in profile view	Narrow elliptic Elliptic Circular	After threshing
1.26	Grain : Size of mark of germ	Very small Small Medium Large Very large	After threshing
1.27	Grain : Texture of endosperm (in longitudinal section)	Fully vitreous (100% corneous) ¾ vitreous (75% corneous) Half vitreous (50% corneous) ¾ farinaceous (25% corneous) Fully farinaceous (0% corneous)	After threshing
1.28	Grain : Colour of vitreous albumen	Greyed yellow RHS 160-162 Greyed orange RHS 166 Greyed purple RHS N 187	After threshing
1.29	Grain : Luster	Non-lustrous Lustrous	After threshing
1.30	Green fodder yield/plant		After harvesting
1.31	Dry fodder yield/plant		After harvesting

Table.2 (a) Mean performance and range of different morphological traits

Genotypes	Natural height of plant upto base of flag leaf (cm)	No. of tillers /plant	No. of leaves /plant	Stem girth (mm)	Anther length (mm)	Stigma length (mm)	Time of panicle emergence (no. of days)	Green fodder yield/plant (g)	Dry fodder yield/plant (g)
BMR-1	94.0	1.8	16.5	10.9	2.3	2.3	102.0	150.5	51.9
BMR-2	137.9	1.3	17.3	9.4	2.8	2.3	62.6	152.7	53.2
BMR-3	**88.0**	1.4	16.5	9.8	2.1	2.3	73.0	127.7	48.6
BMR-4	109.2	1.5	14.0	8.2	3.1	2.0	101.0	165.5	56.2
BMR-5	178.3	1.1	**10.6**	9.9	**2.0**	2.3	79.3	152.2	46.9
COFS 29	173.3	**5.8**	19.3	**5.8**	2.0	2.4	**105.0**	90.5	31.6
HJ 513	194.6	1.4	19.7	12.0	2.5	1.6	78.6	183.3	60.0
HC 260	202.7	1.7	16.5	8.9	3.1	1.6	60.3	147.2	46.5
IS 2205	201.5	1.8	20.2	8.6	3.2	2.2	**59.0**	182.7	58.7
IS 2389	179.5	2.6	24.9	8.9	2.1	1.9	67.6	197.8	65.5
DUGGI	147.9	1.9	20.1	6.4	2.3	**1.0**	68.0	126.6	48.0
CSV 21F	**233.3**	1.7	19.0	8.5	3.3	2.5	80.6	**266.6**	**93.3**
S 490	207.1	1.5	16.4	**12.3**	3.2	1.8	90.3	256.5	93.3
S 437	180.7	1.7	16.3	9.1	3.1	2.3	69.0	173.1	58.0
S 651	208.8	2.2	16.3	11.7	2.0	2.0	89.3	186.9	61.5
G 46	174.0	2.2	20.0	7.4	2.1	**2.5**	60.6	120.0	38.5
SSG 59-3	211.4	2.3	15.4	7.2	**3.3**	2.3	71.6	103.3	38.2
HC 136	151.3	1.9	20.7	5.9	2.3	1.9	91.3	152.2	49.9
HC 171	186.0	**1.0**	12.0	7.5	3.1	**2.5**	91.6	**77.7**	**27.2**
HJ 541	180.4	1.5	19.5	8.2	3.2	2.4	83.0	209.7	48.4
PC 5	151.1	2.6	**30.4**	7.6	2.0	1.4	77.6	182.8	61.0
PC 7	172.7	1.8	18.1	8.0	3.2	2.4	82.0	129.9	41.8
PC 8	148.5	1.7	18.8	9.3	2.4	1.8	95.6	181.6	64.0
ICSV 700	176.9	2.2	17.5	8.4	2.1	1.3	62.0	150.5	58.7
HC 308	104.4	2.2	25.4	7.6	2.5	1.6	89.3	159.5	38.9
Mean	167.7	1.9	18.4	8.7	2.6	2.0	79.4	161.1	53.6
Range	88.0-233.3	1.0-5.8	10.6-30.4	5.8-12.3	2.0-3.3	1.0-2.5	59-105	77.7-266.6	27.2-93.3
C.V %	12.9	17.5	13.7	5.3	10.7	7.8	3.4	11.8	5.1

Table.2 (b) Mean performance and range of different morphological and quality traits

Genotypes	Neck of panicle visible above the sheath (cm)	Panicle :length of branches(cm)	Lignin (%)	IVDMD (%)	Crude protein (%)	NDF (%)	ADF (%)	DDM (q/ha)	Protein yield (q/ha)
BMR-1	3.5	5.1	3.1	60.4	8.3	65.5	36.5	48.8	6.4
BMR-2	7.0	4.6	3.0	60.4	**9.3**	70.1	**36.1**	48.0	7.2
BMR-3	5.0	**4.1**	**2.6**	68.2	9.1	65.6	45.8	38.5	6.0
BMR-4	6.1	7.0	3.0	61.6	8.8	**75.9**	44.6	54.8	7.5
BMR-5	6.5	6.0	4.3	60.2	**8.2**	70.3	46.2	44.0	5.9
COFS 29	12.8	9.3	5.7	60.2	8.4	68.0	56.3	28.3	3.9
HJ 513	17.6	7.0	3.3	65.5	9.0	69.3	37.4	59.8	8.5
HC 260	11.8	12.0	3.7	60.2	8.6	67.3	36.4	52.3	5.8
IS 2205	11.1	8.3	3.5	64.2	8.6	65.3	43.3	58.4	7.6
IS 2389	6.5	7.0	**5.8**	65.2	9.0	67.6	48.4	63.6	8.8
DUGGI	**3.5**	10.0	3.8	65.7	9.0	67.5	43.5	44.9	6.2
CSV 21F	8.0	7.0	3.7	**68.2**	9.4	67.6	43.0	94.4	**13.0**
S 490	7.0	7.0	3.4	68.1	9.0	64.3	42.3	**90.4**	11.9
S 437	4.8	12.3	3.5	60.8	9.2	74.2	42.3	52.9	8.0
S 651	10.6	9.1	5.4	67.2	8.4	67.9	**56.3**	64.0	8.0
G 46	18.0	12.3	3.3	64.0	9.0	64.1	41.7	38.8	5.3
SSG 59-3	**20.6**	13.0	4.5	60.0	9.2	66.2	42.6	32.1	4.6
HC 136	6.5	5.3	5.4	62.3	9.1	68.1	39.6	49.1	6.6
HC 171	11.1	6.3	3.5	66.1	9.3	71.6	43.5	**26.6**	**3.7**
HJ 541	19.0	13.3	3.6	65.1	9.1	68.6	44.2	64.1	8.4
PC 5	8.5	8.0	3.2	66.2	8.9	68.6	44.6	62.7	8.6
PC 7	6.8	8.3	3.2	62.3	8.7	**61.2**	43.3	40.6	5.5
PC 8	5.0	8.0	4.1	**59.4**	8.9	68.3	43.2	56.0	8.6
ICSV 700	16.6	**14.0**	4.7	62.0	9.3	68.5	46.1	68.0	9.9
HC 308	4.5	8.3	3.5	61.8	9.0	68.1	42.2	36.1	9.5
Mean	9.5	8.5	3.9	63.0	8.9	68.0	43.6	52.7	7.4
Range	3.5-20.6	4.1-14.0	2.6-5.8	59.4-68.2	8.2-9.3	61.2-75.9	36.1-56.3	26.6-94.4	3.7-13.0
C.V	10.0	9.4	5.3	0.8	2.1	0.4	0.5	7.5	6.5

Table.3 (a) Analysis of variance for different morphological characters

Source of variation	D. F	Green fodder yield/plant (gm)	Natural height of plant upto base of flag leaf (cm)	No. of leaves/plant	Stem girth (mm)	No. of tillers/plant	Dry fodder yield/plant (gm)	Time of panicle emergence (no. of days)	Stigma Length (mm)	Anther Length(mm)
Replication	2	2291.66	503.34	88.61	0.012	3.72	8.87	53.32	0.27	0.03
Genotype	24	5939.64**	4383.75**	51.13**	8.58**	2.46**	735.46**	566.6**	0.51**	0.80**
Error	48	367.07	475.21	6.47	0.21	0.12	7.54	7.65	0.02	0.08

* Significant at 5% level; **significant at 1% level

Table.3 (b) Analysis of variance for different morphological and quality characters

Source of variation	D.F	Panicle :length of branches (cm)	Neck of panicle above sheath (cm)	Lignin %	IVDMD %	C.P %	NDF %	ADF %	DDM (q/ha)	Protein yield (q/ha)
Replication	2	5.96	3.62	0.03	0.05	0.007	0.10	0.005	38.19	0.05
Genotype	24	24.53**	81.14**	2.36**	25.96**	0.332**	28.09**	73.62**	833.05*	15.10**
Error	48	0.65	0.91	0.04	0.26	0.03	0.09	0.06	15.63	0.24

* Significant at 5% level; **significant at 1% level

In present investigation results from variability studies revealed that crude protein and IVDMD varied from 8.2 to 9.4 % and 59.4 to 68.2 %, respectively. Findings of present investigation is in close conformation with the findings of Gupta *et al.,* (2002) who revealed that protein and IVDMD varied from 3.01 to 8.75 and 40.40 to 66.16 %, respectively. Singh *et al.,* (2010) reported that protein content in single cut (SC) and multicut (MC) genotypes ranged from 5.24 to 10.06 and 4.81 to12.47 per cent, respectively. Similarly, IVDMD ranged from 50.4 to 62.0 and 48.3 to 62.2 per cent, respectively. In present investigation genotypes BMR-2, HC 171 (9.3) and S 437 (9.2) observed high crude protein and BMR-3 (68.2), S 490 (68.1) and S 651 (67.2) observed high IVDMD. Digestible dry matter (DDM) is the portion of the dry matter in a feed that is digested by animal at specific level of feed intake. DDM ranged from 26.6 q/ha to 94.4 q/ha, being maximum in CSV 21F (94.4). The digestibility of sorghum fodder is affected by cell wall constituents' *viz.*, NDF, ADF and lignin. NDF measures total cell wall content of plant. The concentration of NDF in feeds is negatively correlated with energy concentration and lowers the quality of forage. As ADF increases, digestibility and nutrient availability decreases. In our findings NDF, ADF, and lignin ranged from 61.2 to 75.9, 36.1 to 56.3 and 2.6 to 5.8 per cent, respectively. These results are in conformity with that of Grenier *et al.,* (2001) who reported that NDF, ADF, and lignin ranged from 57.48 to 70.00, 30.85 to 42.80 and 3.80 to 7.00 per cent, respectively. All BMR genotypes show low amount of lignin in BMR-3, BMR-2, BMR-4, BMR-1 *i.e.* 2.6, 3.0, 3.0, 3.1 respectively.

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