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MORPHOLOGICAL DIVERGENCE AND CHARACTER ASSOCIATION FOR YIELD COMPONENTS IN SEWAN GRASS ACCESSIONS UNDER HOT ARID ECOSYSTEM OF INDIA

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SUMMARY

Globally sewan grasslands are predominantly found in arid and semi-arid tropics with other arid grasses. Thirty sewan accessions selected based on dry matter yield were evaluated to assess genetic variability, correlations and divergence for agronomical traits and yield. Trait dry matter yield showed significant positive correlation and direct effect with green fodder yield and dry matter percentage while negative direct effect with positive significant correlation with number of tillers per plant. These traits also had a significant regression with dry matter yield that explained 16.2, 15.8, and 87.2 % respectively of the variation. Variability revealed that two traits *viz.,* tillers number and leaf length showed high coefficient of variation. Using metroglyph plot, accessions were classified into seven clusters. Accessions RLSB 6-17, RLSB 5-24, RLSB 2-11, RLSB 10-28 and RLSB 7-19 were identified as highly diverse accessions that can be used for further improvement in sewan grass for harsh arid and semi-arid environmental conditions. Principal component analysis illustrated that leaf length, days to maturity, leaf width, spike length and plant height traits had the highest communality and consequently high relative contribution in forage yield.

Key words : Desert grassland, diversity, sewan grass, selection, forage

Globally, more than 200 million people use rangelands for pastoral production, whereas 30 to 40 millions of these people are entirely depend on livestock (Singh *et al.,* 2014). Rangeland ecosystems play significant roles to boost livestock productivity, livelihood and rural economics in India but due to heavy grazing pressures, these grasslands have been deteriorated largely and need revitalization for sustainable production (Roy *et al.,* 2019). Sewan grasslands are extensively found in arid or semi-arid regions that are unsuited to rainfed area, industrial forestry, protected forests or urbanization (Parwani and Mankad, 2013). Sewan grass (*Lasiurus sindicus* Henr.) is the perennial nature grass popularly known as the 'King of desert grasses' (Sharma *et al.,* 2017), belongs to the Poaceae family, which is mostly found in the area with lower rainfall (100 mm annually) including the dry areas of North Africa, Sudanese and Sahelian regions, East Africa and Asia (Singh and Singh, 1997; Sharma *et al.,* 2017). Nutritious composition in this grass contains crude protein (4.6-5.0 %), crude fiber (31-35 %), ash (4.5 %), NDF (72 %), ADF (38 %) and ether extracts (2 %) (Nehra *et al.,* 2008; Sanadya *et al.,* 2021). Sewan grass a promising, drought-tolerant, tussocky grass suitable for pasture development (Gupta and Sharma, 1971). It assumes importance as not only livestock feed but also as soil binders, improve the soil fertility and aid in soil conservation. Small ruminants (goat, sheep) make the major contribution to agriculture based value-added services in the arid and semi-arid areas and sewan among all the arid grasses is play most important roles for livestock feed. Conservation and propagation of sewan grass pastures require priority for small ruminants. Further the vast lands of arid region of India need to be rehabilitated with grass pasture to ensure round the year supply of quality forages to animals (Shinde and Mahanta, 2020).

The variability in plant population is the first requirement for crop improvement. The amount of variability in the accessions of any crop sets the limits of progress that can achieve through selection (Govindraj *et al.,* 2015). The metroglyph analysis found to be useful for preliminary classification of accessions and its divergence study (Anderson, 1957). Coupled with principal component analysis (PCA), this could be of great use in preliminary screening and classification of germplasm when a large number of germplasm are available (Datta *et al.,* 2013). Correlation analyses can a tool to have success in breeding programs especially for yield traits in order to increase the yield (Bibi *et al.,* 2016). Regression used to define the importance of yield traits to use as effective indexes to increase yield (Wang *et al.,* 2011). Path analysis enables us to partitioning of correlation into direct and indirect effects of different traits on yield. The present study was conducted to estimate the correlation, direct and indirect effects on dry matter yield and to predict effect on dry matter yield through regression analysis to define selection criteria for forage yield as well as classified different accessions into clusters using metroglyph method coupled with PCA.

MATERIALS AND METHODS

All the sewan grass accessions were established in germplasm block of AICRP on Forage Crops and Utilization, Agricultural Research Station, SKRAU, Bikaner prevailing 28°10'N latitude 73°18' E longitude and 223.88 meter above mean sea level on well aerated sandy soil. Accessions have been raised into the unreplicated design (single plant acts as one plot) with length spaced at 1m between rows and 1m between plants. The observations were recorded for eleven characters namely days to 50% flowering (DF), days to complete seed maturity (DM), plant height (PH), numbers of tillers per plant (NOT), leaf length (LL), leaf width (LW), spike length (SL), green fodder yield per plant (GFY), leaf: stem ratio (LSR), dry matter percentage (DM%) and dry matter yield per plant (DMY). For the traits leaf length, leaf width and spike length five observations were recorded on each plant and averaged to obtain mean. However, sewan grass is a perennial nature so that observations were recorded on first cut from June 1, 2017 to September 10, 2017. Biometrical methods such as variability parameters (Burton 1952), correlation (Johnson *et al.,* 1955), path coefficient (Dewey and Lu, 1959), regression coefficient (Hair, 1995), metroglyph analysis (Anderson, 1957), Principal Component Analysis (Pearson, 1901) were statistically analyzed for thirty accessions with high dry matter yield. Analysis of quantitative traits using skewness and kurtosis parameters provide the information about the quantum and nature of gene action controlling the traits (Fisher *et al.,* 1932). Statistical analysis was performed in Microsoft Excel 2007 (Microsoft Corp., Redmond, WA, USA) and R package software.

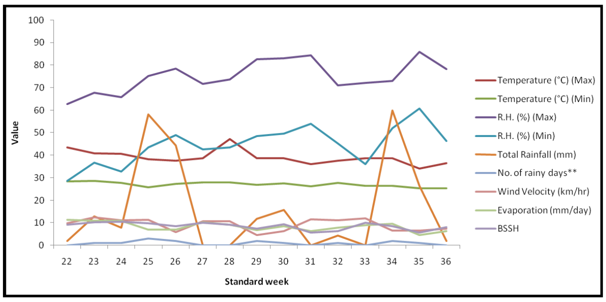

Fig. 1. Weekly meteorological observations recorded in kharif-2017 at ARS, Bikaner.

RESULTS AND DISCUSSION

Mean performance of 273 accessions of sewan grass : Mean performance of 30 accessions out of 273 accessions of sewan grass based on dry matter yield was mentioned in the Table 1. Based on the mean performance of sewan grass accessions, under the arid or semi-arid environmental conditions, the high mean value is the significant for all the traits except days to 50% flowering and days to complete seed maturity. After analyzing the mean performance of 273 accessions, it was found that 186 accessions for days to 50 % flowering, 173 for days to complete seed maturity, 143 plant height, 89 number of tillers per plant, 125 for leaf length, 133 for leaf width, 107 for days spike length, 109 for green fodder yield per plant, 105 for dry matter yield per plant, 111 for dry matter percentage and 118 for leaf stem ratio were out performed over their grand mean (GM) values in desirable direction, respectively. According to the mean performance of the studied accessions, it is observed that few of them can be selected for their better performance, such as RLSB 4-24 and RLSB 11-17 for the lowest days to 50% flowering (34 days), RLSB 1-19, RLSB 9-2, RLSB 9-3, RLSB 7-1, RLSB 8-32, RLSB 9-27, RLSB 4-7, RLSB 7-36, RLSB 11-41, RLSB 4-25, RLSB 8-41 and RLSB 11-50 for similar days to complete seed maturity (66 days), RLSB 1-19, RLSB 11-50, RLSB 9-29, RLSB 10-1, RLSB 8-4, RLSB 11-26 and RLSB 2-15 for the high plant height (more than 100 cm), RLSB 2-45, RLSB 1-41, RLSB 4-43, RLSB 1-19 and RLSB 9-23 for number of tillers per plant (more than 100 tillers), RLSB 2-11 and RLSB 2-15 for the high leaf length (more than 40 cm), RLSB 9-11 for the highest leaf width (0.80 cm), RLSB 5-24 for the highest spike length (14.50 cm), RLSB 1-41 and RLSB 10-1 for the high green fodder yield per plant (1.971 and 1.806 kg, respectively), RLSB 4-37 and RLSB 1-41 for the high dry matter yield per plant (more than 0.800 kg), RLSB 2-15 and RLSB 7-29 for

TABLE 1

Mean performance of 30 best sewan grass accessions based on dry ammeter yield for eleven characters

S. No.	Accessions no.	DF	DM	PH	NOT	LL	LW	SL	GFY	DMY	DM%	LSR
1.	RLSB 4-37	37	70	90.1	75	26.56	0.6	9.16	1.327	0.825	62.19	0.5
2.	RLSB 1-41	36	68	91.1	125	17.32	0.48	9.6	1.971	0.806	40.89	1.24
3.	RLSB 9-23	51	89	30.5	111	20	0.64	9.8	0.18	0.76	42.22	0.89
4.	RLSB 1-27	36	69	98.4	49	20.98	0.56	7.08	1.753	0.713	40.66	0.82
5.	RLSB 11-50	43	66	109.3	20	22.42	0.42	7.78	1.347	0.616	45.7	0.74
6.	RLSB 10-1	39	75	107.3	95	22.52	0.48	11.06	1.806	0.598	33.1	0.88
7.	RLSB 1-38	37	71	74.3	69	23.26	0.38	7.64	1.34	0.586	43.75	0.85
8.	RLSB 8-4	39	71	103.4	43	30.36	0.6	7.8	1.163	0.553	47.53	0.56
9.	RLSB 2-45	37	68	83.4	140	22.72	0.42	7.42	1.31	0.537	40.99	0.99
10.	RLSB 4-41	48	81	76.2	11	22.48	0.32	9.76	1.187	0.52	43.79	1.48
11.	RLSB 8-6	37	72	80.6	50	19.26	0.66	7.64	0.967	0.501	51.79	0.64
12.	RLSB 11-26	39	71	102.1	20	15.1	0.5	8.76	1.128	0.486	43.05	0.77
13.	RLSB 9-14	38	69	84.3	55	28.12	0.54	7.62	0.76	0.482	63.38	0.56
14.	RLSB 4-43	37	71	84.3	125	19.32	0.32	8.14	1.154	0.455	39.41	0.89
15.	RLSB 10-17	39	72	93.8	34	24.46	0.58	10.08	1.067	0.448	41.98	1.09
16.	RLSB 4-31	37	72	90.1	79	32.72	0.5	7.5	0.965	0.44	45.62	0.89
17.	RLSB 10-23	38	71	78.3	89	35.34	0.56	8.52	1.167	0.437	37.42	1.29
18.	RLSB 3-26	38	68	96.4	24	39.52	0.54	7.46	1.065	0.422	39.62	1.21
19.	RLSB 11-47	42	70	55.3	12	25.16	0.34	7.14	1.203	0.416	34.57	0.96
20.	RLSB 1-19	36	66	110.3	116	36.18	0.48	8.72	1.031	0.414	40.15	0.59
21.	RLSB 2-46	38	70	73.2	42	23.32	0.4	7.16	0.97	0.406	41.82	0.79
22.	RLSB 10-28	42	72	39.3	58	28.98	0.66	9.88	0.706	0.405	57.36	0.92
23.	RLSB 5-35	38	74	90.8	39	16.38	0.4	8.02	0.782	0.392	50.18	0.82
24.	RLSB 5-24	41	75	86.3	26	26.02	0.5	14.5	0.761	0.39	51.26	0.8
25.	RLSB 11-19	39	70	72.3	6	16.86	0.54	7.62	0.847	0.389	45.86	0.75
26.	RLSB 6-17	37	74	99.1	55	28.34	0.54	8.7	0.846	0.382	45.18	0.96
27.	RLSB 4-21	37	71	79.3	48	17.36	0.46	7.18	1.02	0.38	37.28	1.16
28.	RLSB 7-25	39	70	80.6	87	27.04	0.4	7.58	0.963	0.38	39.43	0.57
29.	RLSB 11-7	37	70	94.3	57	21.12	0.42	7.82	0.927	0.379	40.93	0.69
30.	RLSB 3-28	38	70	97.4	65	26.9	0.56	8.08	0.924	0.376	40.74	0.78
	Minimum	34	66	14.90	1	9.80	0.22	3.18	0.048	0.032	18.97	0.50
	Maximum	75	95	110.30	140	41.16	0.80	14.50	1.971	0.825	89.33	1.56
	Mean	42.35	72.62	66.86	20.71	22.35	0.50	8.02	0.49	0.202	40.87	0.95
	SD	6.59	5.57	18.69	23.79	6.14	0.11	1.14	0.31	0.14	8.70	0.19

Note: Minimum, Maximum, average and standard deviation were recorded for all 273 accessions while in this table only top most thirty accessions mean performance was presented.

DF= Days to 50% flowering, DM= days to complete seed maturity, PH= plant height, NOT= numbers of tillers per plant, LL= leaf length, LW= leaf width, SL= spike length, GFY= green fodder yield per plant, LSR= leaf: stem ratio, DM%= dry matter percentage and DMY= dry matter yield per plant.

the high dry matter percentage (approx. 89 percent) and RLSB 11-32 and RLSB 9-12 for the highest leaf stem ratio (1.56).

Variability parameters : The estimates of variability parameters for yield and its component characters have been mentioned in Table 2. Result revealed that the accession RLSB 9-14 recorded high *per se* performance for dry matter yield per plant followed by RLSB 10-28, RLSB 5-35, RLSB 5-24 and RLSB 11-19. Therefore, these accessions can utilize in further breeding programme for developing superior varieties for dry matter yield or any related character in sewan grass. The increased dry matter yield per plant in accession RLSB 9-14 was due to higher mean values of plant height, dry matter percentage, green fodder yield per plant and number of tillers per plant. The accessions RLSB 8-44 (67 days) and RLSB 10-8 (67 days) recorded early maturity and RLSB 1-11, RLSB 2-36, RLSB 1-50 and RLSB 10-38 recorded early flowering. Similar results were reported earlier

(Shekhawat *et al.,* 2003; Sanadya *et al.,* 2018; Sanadya *et al.,* 2019) in sewan grass for few traits. The estimates of coefficient of variation (CV) observed high (>53 %) for number of tillers per plant (79.06 %) similar result reported by Sanadya *et al.,* (2018), whereas it was moderate (26-52 %) for leaf length and rest of traits having low CV (<26%) value. Similar results were found earlier by Sanadya *et al.,* (2019) in few traits of sewan grass. In present investigation, all the traits showed continuous variation, among them most of the traits showed asymmetrical normal distribution except two traits plant height and leaf length as evidenced from the skewness (indicates the sign of asymmetry and deviation from normality) and kurtosis (indicates the peakness or flatness of normal distribution curve) parameters. In this study, all the traits except plant height exhibited a right tailed distribution (Table 1). Trait plant height showed a left skewed distribution. The skewed distribution of this trait could be attributed to the presence of non-additive gene action and the trait is subjective to the influence of environmental variables. Considering kurtosis, all the traits except spike length showed a platykurtic distribution. The traits with leptokurtic and platykurtic distribution are known to be governed by fewer and larger number of genes, respectively.

Correlation coefficient analysis : The correlation of green fodder yield per plant was positive

TABLE 2

Estimates of variability parameters of the thirty accessions of sewan grass

Character	Range	Mean	Median	Variance	CV	SEm	Skewness	Kurtosis
DF	36-51	40.0	39.50	12.76	8.89	0.56	1.18	1.78
DM	67-75	71.0	70.50	6.41	3.57	0.30	0.12	-1.38
PH	39.3-107.0	78.2	78.70	252.80	20.33	1.80	-0.49	0.08
NOT	2-64	24.03	19.50	361.07	79.06	3.88	0.64	-0.77
LL	12.50-41.20	23.53	22.69	45.44	28.65	1.39	0.49	0.13
LW	0.36-0.74	0.54	0.52	0.01	20.21	0.15	0.21	-1.14
SL	5.30-14.50	8.36	7.88	2.65	19.47	0.56	1.80	6.15
GFY	0.675-0.862	0.759	0.75	0.01	7.22	0.06	0.39	-0.83
DM %	24.74-63.38	41.20	40.07	61.51	19.04	1.22	0.58	1.95
DMY	0.185-0.482	0.313	0.30	0.01	20.82	0.12	0.38	0.29
LSR	0.56-1.40	0.90	0.88	0.03	19.45	0.18	1.04	1.91

DF= Days to 50% flowering, DM= days to complete seed maturity, PH= plant height, NOT= numbers of tillers per plant, LL= leaf length, LW= leaf width, SL= spike length, GFY= green fodder yield per plant, LSR= leaf: stem ratio, DM%= dry matter percentage and DMY= dry matter yield per plant.

TABLE 3

Phenotypic correlation coefficient analysis among characters

Character	DM	PH	NOT	LL	LW	SL	GFY	DM %	DMY	LSR
DF	0.168	-0.243	-0.367*	-0.082	-0.034	0.211	-0.031	-0.022	-0.037	0.224
DM		0.204	0.102	0.375*	0.090	0.419*	-0.105	0.260	0.202	0.059
PH			0.340	0.182	-0.034	0.200	0.101	-0.077	-0.021	0.017
NOT				0.470**	0.263	0.298	0.231	0.400*	0.436*	-0.160
LL					0.343	0.192	0.005	0.072	0.068	0.005
LW						0.191	0.059	-0.044	-0.015	0.124
SL							-0.056	0.218	0.175	-0.187
GFY								0.089	0.432*	-0.02
DM %									0.936**	-0.216
DMY										-0.206

*p<0.05, **p<0.01

DF= Days to 50% flowering, DM= days to complete seed maturity, PH= plant height, NOT= numbers of tillers per plant, LL= leaf length, LW= leaf width, SL= spike length, GFY= green fodder yield per plant, LSR= leaf: stem ratio, DM%= dry matter percentage and DMY= dry matter yield per plant.

and significant at phenotypic level with dry matter yield per plant. This character needs due consideration during any selection method. Similar findings of positive and significant correlation had reported by Sanadya *et al.,* (2018). The correlation of dry matter yield per plant was positive and significant at phenotypic level with dry mater percentage, number of tillers per plant and green fodder yield per plant (Table 3). Our results also agree with previous findings Ramakrishanan *et al.,* (2013) in guinea grass and Sanadya *et al.,* (2018) in sewan grass. The trait Days to 50% flowering showed negative and significant correlation with number of tillers per plant. The trait days to complete seed maturity showed positive and significant correlation with spike length. Number of tillers per plant showed positive and significant correlation with days to complete seed maturity, dry matter percentage and leaf length.

Path coefficient analysis : In the present study, path coefficients carried out by taking dry matter yield per plant as dependent variable to partition the correlation coefficient into direct and indirect effect in order to determine the contribution of different characters towards the dry matter yield per plant (Table 4). Results of path analysis indicated that the direct effect of dry matter percentage on dry matter yield per plant was positive and high (0.9161) while other indirect effects of dry matter percentage positive or negative were all neglected which means that dry matter percentage really effect the dry matter yield since the direct effect is almost equal to the correlation value. Direct effect of green fodder yield per plant on dry matter yield per plant was high and positive (0.3525) while other indirect effects of green fodder yield per plant were neglected but negative which minimize the total effect (correlation value) but it still high and positive (0.432*), that means relation between green fodder yield and dry matter yield per plant is effective. Similar findings reported by Ramakrishanan *et al.,* (2013) in guinea grass. Direct negative effect recorded for number of tillers per plant (-0.0258) followed by days to 50 % flowering (-0.0064), spike length (-0.0045) and leaf stem ratio (-0.0066). Similar findings reported by Sanadya *et al.,* (2019) in sewan grass. Path analysis further revealed that direct effect of dry matter percentage and green fodder yield per plant were of high magnitude. The residual effect (0.0010) was low, which indicated choices of traits in the study were able to explain the most effects on dry matter yield.

Regression analysis : Results showed significant regression and each of days to complete seed maturity, number of tillers per plant, spike length, green fodder yield per plant, dry matter percentage and leaf: stem ratio as independent variables, while other traits like days to 50% flowering, plant height, leaf length and leaf width hadn't any effect on dry matter yield as the regression wasn't meaningful (Table 5). The adjusted coefficient of determination (R^2) between dry matter yield and each of number of tillers per plant, green fodder yield per plant and dry matter percentage was (0.162, 0.158 and 0.872) respectively, which means that about 16.2 % of variation in dry matter yield per plant could be explained by the variation in number of tillers per plant and each of green fodder yield and dry matter percentage can explain (15.8%,

TABLE 4

Path coefficient analysis among characters on dry matter yield per plant

Traits	DF	DM	PH	NOT	LL	LW	SL	GFY	DM %	LSR	DMY
DF	-0.0064	0.0000	-0.0052	0.0095	-0.0003	-0.0004	-0.0010	-0.0109	-0.0203	-0.0015	-0.037
DM	-0.0011	0.0001	0.0044	-0.0026	0.0016	0.0011	-0.0019	-0.0370	0.2382	-0.0004	0.202
PH	0.0016	0.0000	0.0213	-0.0088	0.0008	-0.0004	-0.0009	0.0356	-0.0702	-0.0001	-0.021
NOT	0.0023	0.0000	0.0073	-0.0258	0.0020	0.0033	-0.0014	0.0813	0.3663	0.0011	0.436*
LL	0.0005	0.0000	0.0039	-0.0121	0.0042	0.0043	-0.0009	0.0018	0.0659	0.0000	0.068
LW	0.0002	0.0000	-0.0007	-0.0068	0.0014	0.0125	-0.0009	0.0208	-0.0404	-0.0008	-0.015
SL	-0.0014	0.0000	0.0043	-0.0077	0.0008	0.0024	-0.0045	-0.0199	0.1999	0.0012	0.175
GFY	0.0002	0.0000	0.0022	-0.0059	0.0000	0.0007	0.0003	0.3525	0.0820	0.0001	0.432*
DM %	0.0001	0.0000	-0.0016	-0.0103	0.0003	-0.0006	-0.0010	0.0316	0.9161	0.0014	0.936**
LSR	-0.0014	0.0000	0.0004	0.0041	0.0000	0.0016	0.0008	-0.0070	-0.1979	-0.0066	-0.206

Residual effect 0.0010; *p<0.05, **p<0.01

DF= Days to 50% flowering, DM= days to complete seed maturity, PH= plant height, NOT= numbers of tillers per plant, LL= leaf length, LW= leaf width, SL= spike length, GFY= green fodder yield per plant, LSR= leaf: stem ratio, DM%= dry matter percentage and DMY= dry matter yield per plant.

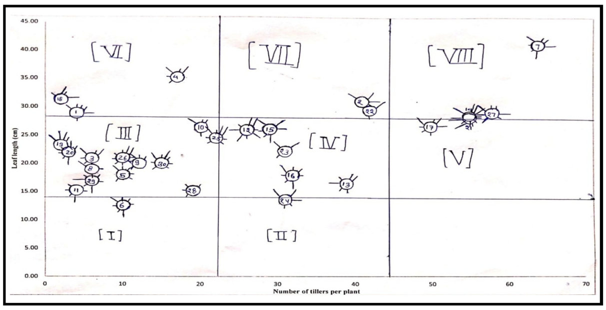

Fig. 2. Scattered diagram of metroglyph analysis of sewan grass accessions.

87.2%) of dry matter yield. Simple linear regression equations formed for the significant traits.

Metroglyph analysis : The accessions plotted taking number of tillers per plant on X-axis and leaf length on Y-axis as these two characters exhibited high CV. The range of each character divided into three equal classes (low, medium and high, respectively) and each character represented by different length of the ray based on their index score. Low; medium and high scores were represented with 1, 2 and 3, respectively according to their range mean of mean values (Table 6). The thirty accessions of sewan grass graphically represented as metroglyph (Fig. 2).

Group I containing the accession RLSB 2-7 placed farthest from the group VIII with RLSB 2-11. RLSB 2-7and RLSB 2-11 had contrasting mean values for both the axes. Thirty accessions of sewan grass grouped into eight clusters among Groups I and II, containing only one accession each, groups V and VII contain two accessions each, groups VI and VIII, containing three accessions each, group IV having five accessions and group III, comprising of thirteen accessions were placed closely on the scattered plot. The accessions of group IV had medium values for both axes. The total index score values recorded for accessions ranged from 15 to 27. The accession RLSB 6-17 showed the highest score (27), while RLSB 2-36 and RLSB 10-38 showed the lowest score (15). The accessions, which had the index score from 22 to 27, constituted the upper (superior) class and the accessions, which were between the index score of 15 to 21 constituted the lower (inferior), class (Table 7). Several workers had suggested metroglyph analysis for preliminary classification of genotypes in different

TABLE 5

Summary of regression between dry matter yield and other traits

Trait	Source of variation	Df	Mean square	R	R^2	Adjusted R^2
DF	Regression	1	0.000148^{NS}	-0.037	0.0013	-0.034
	Residual	28	0.004			
DM	Regression	1	0.005^{S}	0.202	0.0409	0.007
	Residual	28	0.004			
PH	Regression	1	0.000048^{NS}	-0.021	0.0004	-0.035
	Residual	28	0.004			
NOT	Regression	1	0.024^{S}	0.436*	0.1905	0.162
	Residual	28	0.004			
LL	Regression	1	0.001^{NS}	0.068	0.0046	-0.031
	Residual	28	0.004			
LW	Regression	1	0.000024^{NS}	-0.015	0.0002	-0.036
	Residual	28	0.004			
SL	Regression	1	0.003548^{S}	0.175	0.0307	-0.004
	Residual	28	0.004			
GFY	Regression	1	0.023^{S}	0.432*	0.1867	0.158
	Residual	28	0.004			
DM %	Regression	1	0.108^{S}	0.936**	0.8761	0.872
	Residual	28	0.001			
LSR	Regression	1	0.005^{S}	-0.206	0.0424	0.008
	Residual	28	0.004			

*$p<0.05$, **$p<0.01$; Significance, NS Non-significance

DF= Days to 50% flowering, DM= days to complete seed maturity, PH= plant height, NOT= numbers of tillers per plant, LL= leaf length, LW= leaf width, SL= spike length, GFY= green fodder yield per plant, LSR= leaf: stem ratio, DM%= dry matter percentage and DMY= dry matter yield per plant.

TABLE 6
Index score and signs used for nine characters for metroglyph analysis of 30 sewan accessions

S. No.	Traits	Score1		Score2		Score3	
		Value less than	Sign	Value from-to	Sign	Value more than	Sign
1	DF	36-41		42-46		47	
2	DM	67-70		71-73		74	
3	PH	39.3-61.0		61.1-83.0		83.1	
4	LW	0.36-0.48		0.49-0.62		0.63	
5	SL	5.3-8.4		8.5-11.8		11.9	
6	GFY (kg)	0.675-0.737		0.738-0.800		0.801	
7	DM %	24.74-37.40		37.41-50.40		50.41	
8	DMY (kg)	0.185-0.280		0.281-0.380		0.381	
9	LSR	0.56-0.70		0.71-0.84		0.85	

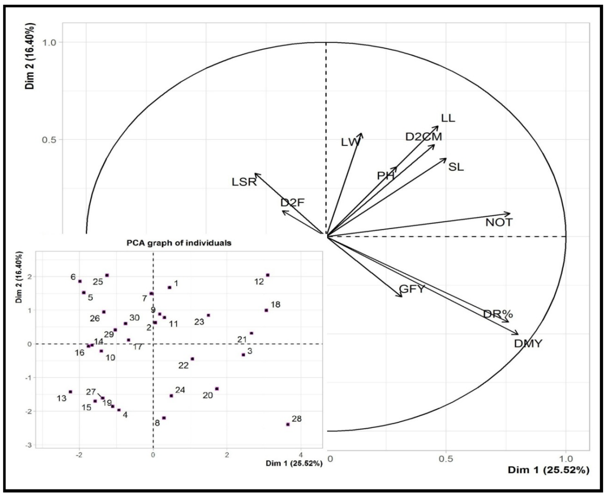

Fig. 3. Dispersion of sewan grass accessions and traits on the two first axes of principal component analysis.

crop plants (Punitha *et al.,* 2010; Jha *et al.,* 2011; Kang *et al.,* 2013; Jhakar *et al.,* 2019; Soharu *et al.,* 2021) and Sanadya *et al.*, (2018) in same grass. Pictorial representation of accessions (Fig. 1) as brought about by the scattered plot of metroglyph analysis can use as a measure of relative genetic distance among the accessions. On the basis of their total index score, highly diverse accessions *i.e.* RLSB 6-17, RLSB 5-24, RLSB 2-11, RLSB 10-28 and RLSB 7-19 while less diverse accessions *i.e.* RLSB 2-36, RLSB 10-38, RLSB 9-15, RLSB 3-8, RLSB 2-36 and RLSB 4-1 and RLSB 5-3 were reported.

Principal Component Analysis : PCA was performed on sewan grass accessions for yield and its component traits. Out of 11, five principal components (PCs) exhibited more than one eigenvalue and showed about 75.81% total variability among the traits (Table 8). The PCA results revealed that the first five PCA axes explained 25.52%, 16.40%, 14.15% 10.65% and 9.10% of the overall variation. Principal component 1 (PC_1) accounted for the maximum variability and highly loaded with traits such as DM, NOT, LL, SL, DM % and DMY that clearly revealed that the variation in PC_1 is mainly accounted by yield contributing characters (Table 8). Principal component

TABLE 7
A total index score of sewan grass accessions for eleven characters

Accessions	DF	DM	PH	NOT	LL	LW	SL	GFY	DM %	DMY	LSR	Total score
RLSB 1-1	2	2	2	1	2	3	1	2	1	1	3	20
RLSB 1-11	1	1	3	2	3	3	2	1	1	1	3	21
RLSB 1-39	1	2	3	1	1	1	1	1	2	2	3	18
RLSB 1-50	1	2	3	1	3	1	1	1	2	2	3	20
RLSB 2-5	2	1	2	1	1	2	2	1	2	1	3	18
RLSB 2-7	2	1	2	1	1	2	1	3	2	2	3	20
RLSB 2-11	1	2	2	3	3	3	1	3	2	2	3	25
RLSB 2-36	1	1	1	1	1	2	1	2	1	1	3	15
RLSB 3-8	2	1	2	1	1	1	1	1	2	2	3	17
RLSB 4-1	1	2	2	1	2	1	1	2	1	1	3	17
RLSB 5-3	1	1	1	1	1	2	1	3	2	2	2	17
RLSB 5-24	1	3	3	2	2	2	3	2	3	3	2	26
RLSB 5-35	1	3	3	2	1	1	1	2	2	3	2	21
RLSB 6-17	1	3	3	3	2	2	2	3	2	3	3	27
RLSB 6-18	1	1	3	2	2	3	1	3	2	2	3	23
RLSB 7-2	2	1	2	2	1	2	1	3	2	2	3	21
RLSB 7-19	1	2	3	3	2	3	1	2	2	2	3	24
RLSB 7-24	1	3	2	1	3	3	1	1	1	1	2	19
RLSB 8-24	3	3	2	1	2	1	2	1	1	1	3	20
RLSB 8-44	3	1	2	1	2	1	1	3	2	2	2	20
RLSB 9-14	1	1	3	3	2	2	1	2	3	3	1	22
RLSB 9-15	1	1	3	2	2	1	1	2	1	1	1	16
RLSB 9-29	1	1	3	2	2	1	1	1	2	1	3	18
RLSB 10-8	1	1	3	2	1	3	2	2	1	1	3	20
RLSB 10-10	2	3	3	1	2	2	2	1	2	2	3	23
RLSB 10-11	2	3	3	1	2	2	2	2	2	2	2	23
RLSB 10-28	2	2	1	3	2	3	2	1	3	3	3	25
RLSB 10-38	1	1	2	1	1	1	1	1	2	2	2	15
RLSB 11-19	1	1	2	1	1	2	1	3	2	3	2	19
RLSB 11-28	2	3	2	1	1	2	2	1	2	2	3	21
Total	43	53	71	48	52	58	41	56	55	56	78	611

DF= Days to 50% flowering, DM= days to complete seed maturity, PH= plant height, NOT= numbers of tillers per plant, LL= leaf length, LW= leaf width, SL= spike length, GFY= green fodder yield per plant, LSR= leaf: stem ratio, DM%= dry matter percentage and DMY= dry matter yield per plant.

TABLE 8
Cumulative variability of principal components for 30 sewan grass accessions and contribution of traits towards PCA

Principal components and traits	PC1	PC2	PC3	PC4	PC5
Eigenvalue	2.81	1.80	1.56	1.17	1.00
Percentage of variance	25.52	16.40	14.15	10.65	9.10
Cumulative percentage of variance	25.52	41.92	56.06	66.71	75.81
DF	-0.11	0.10	0.64	0.17	0.15
DM	**0.27**	0.35	0.35	-0.19	0.23
PH	0.18	0.27	-0.36	-0.22	0.62
NOT	**0.46**	0.09	-0.33	0.08	-0.09
LL	**0.28**	0.42	-0.12	0.11	-0.19
LW	0.09	0.40	-0.02	0.47	-0.47
SL	**0.30**	0.30	0.27	-0.25	-0.03
GFY	0.19	-0.23	-0.16	0.56	0.33
DM%	**0.45**	-0.33	0.26	-0.04	-0.07
DMY	**0.48**	-0.38	0.17	0.16	0.06
LSR	-0.18	0.24	0.13	0.49	0.40

DF= Days to 50% flowering, DM= days to complete seed maturity, PH= plant height, NOT= numbers of tillers per plant, LL= leaf length, LW= leaf width, SL= spike length, GFY= green fodder yield per plant, LSR= leaf: stem ratio, DM%= dry matter percentage and DMY= dry matter yield per plant.

2 (PC2) accounted (16.40 %) of total variability and filled with the characters like DM, PH, LL, LW, SL, GFY, DM %, DMY and LSR. PCA for the measured traits of sewan grass are given in Table 6 and results indicated that LL, DM, LW, SL and PH traits had the highest communality and consequently the high relative contribution in sewan grass yield (Figure 3). This strategy will help in identifying and combining favorable accessions to obtain important traits in one genotype with a broad genetic base. Kharrat-Souissi *et al.,* 2010; Janmohammadi *et al.,* 2014; Soharu *et al.,* 2021 reported almost similar findings in different crops of grass family.

CONCLUSION

Sewan grass is considered as an excellent pasture grass for arid and semi-arid areas and can survive in a wide range of harsh environmental conditions. It can also infer that the scoring procedure would utilize in the preliminary screening of a large number of accessions for selection of germplasm with a desirable combination of various characters influencing the number of tillers per plant with leaf length in sewan grass. It was concluded from this study that correlation and regression analysis are not alone enough to determine the real relationship between traits and dry matter yield, but results showed clear cut importance of number of tillers per plant and dry matter percentage on the dry matter yield per plant. Therefore, forage breeders must concentrate on traits namely number of tillers per plant, green fodder yield and dry matter percentage to increase dry matter yield as well as should select the highly divergent accessions for success of the hybridization breeding programme.

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