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CHARACTERIZATION AND VARIABILITY STUDIES FOR GREEN FORAGE YIELD AND ASSOCIATED TRAITS IN FORAGE CACTUS (*OPUNTIA SPP.*)

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SUMMARY

The present investigation entitled, "Characterization and variability studies for green forage yield and associated traits in forage cactus", was conducted on 34 forage cactus genotypes at Cattle Farm Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra during Summer 2019 – Rabi 2020. The experiment was laid out in Randomized Block Design with two replications and observations were recorded on one plant in each replication for ten characters considered *viz.,* plant height (cm), plant width (cm), number of cladodes (no), cladode length (cm), cladode thickness (cm), dry matter content (%), crude protein content (%), dry matter yield/ plant (kg), green forage yield per plant (kg) in each replication. The analysis of variance revealed that mean sum of squares due to genotypes for all characters studied showed highly significant differences. Based on the mean performance of the 34 genotypes studied, Mexico fodder 1278 was having highest plant height among all other genotypes. COPENA F1 has largest plant width and Orelha de Elephantemaxicana was with highest number of cladodes. Genotype 1280 was with cladode having highest length and width along with highest cladode thickness. Genotype COPENA F1 has the highest dry matter content. Green forage yield is significantly higher of Orelha de elefantemaxicana which also has highest dry matter yield /plant. For all the characters under study genotypes Palma grande, Palma redonda, Orelha de elefantemaxicana, COPENA F1, IPA-90-92, IPA-90-111, IPA-90-156, 1294, 1296, 1280 were found superior for most of the characters.The Characters like plant width, number of cladodes/plant, green forage yield /plant and dry matter yield / plant have high value of GCV and PCV respectively. High heritability combined with high genetic advance is found for all characters except for cladode thickness. Green forage yield/plant showed significantly high and positive correlation with dry matter yield/ plant followed by number of cladodes/plant, dry matter content, cladode thickness, plant width, cladode length and cladode width. Other character like plant height and crude protein content showed positive correlation with the green forage yield but not significant at the genotypic level. In path analysis the high positive and direct effect is of dry matter yield / plant followed by number of cladodes/ plant, cladode width and cladode thickness on green forage yield.

Key words : Forage cactus, variability, correlation , path analysis and green forage yield

Cactus was originated in the deserts of Central and North America native of central Mexico, belong to the family *Cactaceae*. The basic chromosome number in the cactus family is n = 11, and the number in somatic cells is mostly 2n = 22. In countries where cactus is known as cultivated crop and commercially exploited are Brazil, Argentina, South Africa, Israel, USA, Italy and many other American countries. Cultivation of cactus as commercial crop is little known to Indian subcontinent. Only the wild cactus is found to grown in waste land, as hedge around agricultural fields to protect crops from wild animals and as decorative plant in park and home garden. Cactus were introduced into India by the British some-where during 1940s to raise insects for production of natural dyes. Later the plant were introduced by the researchers at Central Arid Zone Research Institute, Jodhpur in late 70s. A scientist Nandini Nimbkar with the help of Dr. Peter Felkar introduced several clones of cactus near Puna (at Phalton) in Nimbkar Agriculture Research Institute as a part of Indo-Us collaborative research programme on Opuntia. Also CSSRI, Karnal (1991), CIAH, Bikaner (1997) and IGFRI, Jhansi (1998) introduced and evaluated cactus accessions for its

growth and potential yields. It is noted that some of these clones fruited in Maharashtra, but the crop did not spread to other arid and semiarid zone of the country because of lack of the coordinated network efforts at the national, state, local or regional level.

Cactus, a succulent and drought-tolerant species, can produce > 20 tones DM /ha/year and provide 180 tones /ha/year of water stored in its cladodes, representing a cost-effective option for livestock watering (Dubeux *et al.*, 2015b). At such levels of productivity, it is possible to at least a 60-fold increase over rangeland productivity. Large number of people live in rural areas in India with their livelihood depending on agriculture. By the report of National Rainfed Area Authority (NRAA) almost 50% of work force and 60% of livestock is dependent on agriculture. Rainfed zone in India is about 60% of the total cultivated area, where only 500-1500 mm, of rainfall is received. Dry lands are also characterized by high evaporation rates, high day temperature low humidity and high soil erosion. The spineless cactus, can grow well in several degraded soils, which are inadequate for other field crops and have great capacity to withstand severe drought conditions and also ideal for responding to global environmental changes. It offers several benefits to mankind and livestock.

MATERIALS AND METHODS

The experimental material consist of thirty four genotypes of forage cactus was sown in randomized block design (RBD) with two replications during

TABLE 1
List of forage cactus genotypes with their source

S. No.	Name of germplasam / Accession number	Species	Source/Origin
1.	Gialla Rocca Palumba	*Opuntia ficus-indica*	Italy
2.	Trunzara Bianca San Cono	*Opuntia ficus-indica*	Italy
3.	Bianca Rocca Palumba	*Opuntia ficus-indica*	Italy
4.	Seedless Santa Margarita Belice	*Opuntia ficus-indica*	Italy
5.	Trunzara Gialla Bronte	*Opuntia ficus-indica*	Italy
6.	Trunzara Biaenca Bronte	*Opuntia ficus-indica*	Italy
7.	Trunzara Gialla San Cono	*Opuntia ficus-indica*	Italy
8.	Gialla San Cono	*Opuntia ficus-indica*	Italy
9.	Bianca San Cono	*Opuntia ficus-indica*	Italy
10.	Trunzara Gialla San Cono -1	*Opuntia ficus-indica*	Italy
11.	Trunzara Bianca Bronte- 1	*Opuntia ficus-indica*	Italy
12.	Palma grande	*Opuntia ficus-indica*	Brazil
13.	Palma redonda	*Opuntia spp.*	Brazil
14.	Orelha de elefante maxicana	*Opuntia stricta Haw.*	Brazil
15.	COPENA F1	*Opuntia ficus-indica*	Brazil
16.	COPENA V1	*Opuntia ficus-indica*	Brazil
17.	IPA-90-92	*Opuntia ficus-indica*	Brazil
18.	IPA-90-111	*Opuntia ficus-indica*	Brazil
19.	IPA-90-115	*Opuntia ficus-indica*	Brazil
20.	IPA-90-156	*Opuntia ficus-indica*	Brazil
21.	Mexico Fodder-1278	*Opuntia ficus-indica*	Brazil
22.	1294	*Opuntia ficus-indica*	Mexico
23.	1248	*Opuntia ficus-indica*	Arizona, USA
24.	1282	*Opuntia ficus-indica*	Mexico
25.	1258	*Opuntia ficus-indica*	Algeria
26.	1278	*Opuntia ficus-indica*	Mexico
27.	1315	*Opuntia ficus-indica*	Chile
28.	1301	*Opuntia ficus-indica*	Mexico
29.	1281	*Opuntia spp.*	Mexico
30.	1326	*Opuntia ficus-indica*	Argentina
31.	1296	*Opuntia ficus-indica*	Mexico
32.	1270	*Opuntia inermis Stricta*	Brazil
33.	1271	*Opuntia ficus-indica*	Brazil
34.	1280	*Opuntia ficus-indica*	Argentina

Summer season of 2019 at Cattle Farm Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra. It is situated in semiarid sub-tropical region at 19° 47' to 19° 57' North latitude and 74° 32' to 74° 19' East longitude with elevation of 657 m above mean sea level. Each genotype was grown at the spacing 2.0 × 1.0 m. The list of genotypes along with their source is presented in Table 1. Observations were recorded at the time of harvesting for ten characters. Plant height was measured from ground level to the tip and plant width is measured by considering the average width of one randomly selected plant, total number of cladode was counted, cladode length and cladode width in centimetres was obtained by taking average of three randomly selected cladodes at the time of harvesting of the plant selected for observation. Thickness is measured with the needle and measured on tape. Cladode harvested from plant selected for observation was weighed on weighing balance for green forage yield. Dry matter yield per plant in kg were calculated from dry matter content with the formula. The dry matter (%) content was estimated by using standard formula. Nitrogen percentage in dry fodder was determined by Microkjeldah's method.Statistical analysis was performed by methods proposed by Panse and Sukhatme (1985). The variability parameters were estimated as suggested by Burton (1952) and Johnson *et al*., (1955). The correlation coefficients were estimated as per the procedure outlined by Singh and Chaudhari (1977), while path coefficients analysis was performed by methods of Dewey and Lu (1959).

RESULTS AND DISCUSSION

The analysis of variance (Table 2) revealed that genotypic difference for all the characters studied were significant, which indicated presence of appreciable amount of variability among the genotypes for the characters among them plant height (cm), plant width (cm), number of cladodes/ plant (No) was noted highly significant. Earlier similar results were reported by Alves *et al*., (2016) for cladode width, cladode length, dry matter yield of cladode and number of cladodes. Tarkegn *et al*., (2017) for number of cladodes, width of cladode and dry matter yield. but contradictory with cladode length. Soni *et al*., (2015) for number of cladodes, length of cladode, width of cladodes thickness of cladode and dry matter content (%) and green cladode yield. Gebreegziabher and Tsegay (2015) reported for dry matter yield, plant height and number of cladodes.

Variability parameters such as range, mean, genotypic variance, phenotypic variance, genotypic coefficient of variation, phenotypic coefficient of variation, heritability, genetic advance and genetic advance as % of mean are presented in Table 3.The phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for all characters. This indicated that, all the characters were influenced by environmental factors. Less difference among these variances indicated that the variability present among the traits is mainly due to genetic factors. The genotypic estimate of variances being important help in measuring contribution of genotype for the expression of particular trait. This is confirmatory with the results of Neder *et al*., (2013) reported for plant height, plant width, cladode thickness, cladode length, cladode width, fresh matter yield and dry matter yield. Alves *et al*., (2016) reported for cladode width, cladode length, and no. of cladodes, indicating that variability in those characters is due to genetic factor.

TABLE 2
Analysis of variance for ten characters of thirty four forage cactus genotypes

S. No.	Character	Replications	Genotypes	Error
	DF	1	32	32
1	Plant height (cm)	6.180	877.736**	50.392
2	Plant width (cm)	11.529	1968.430**	30.234
3	Number of cladodes / plant	1.471	440.538**	3.743
4	Cladode length (cm)	0.007	43.099**	2.666
5	Cladode width (cm)	0.085	16.023**	0.528
6	Cladode thickness (cm)	0.002	0.105**	0.011
7	Dry matter content (%)	0.001	3.973**	0.047
8	Crude protein content (%)	0.257**	1.920**	0.057
9	Green forage yield / plant (kg)	4.165	146.029**	4.049
10	Dry matter yield/plant (kg)	0.019	2.140**	0.044

*, **Significant at 5% and 1 % levels, respectively.

TABLE 3
Estimates of variability parameters for green forage yield and its contributing characters in thirty four forage cactus genotypes

S. No.	Character	Mean	Range	Genotypic variance	Phenotypic variance	GCV (%)	PCV (%)	ECV (%)	Heritability h^2 (bs)	Genetic advance	Genetic advance as % of mean
1.	Plant height (cm)	122.36	88.50-163.00	413.67	464.06	16.62	17.61	5.80	89.14	39.56	32.33
2.	Plant width (cm)	98.53	44.00-180.50	969.10	999.33	31.59	32.08	5.58	96.97	63.15	64.09
3.	Number of cladodes/plant	31.73	17.50-80.00	218.40	222.14	46.57	46.97	6.09	98.31	30.19	96.01
4.	Cladode length (cm)	27.48	19.54-34.50	20.22	22.88	16.36	17.41	5.94	88.35	8.71	31.68
5.	Cladode width (cm)	16.34	12.84-27.60	7.75	8.28	17.03	17.61	4.45	93.63	5.55	33.95
6.	Cladode thickness (cm)	2.21	1.70-2.67	0.05	0.06	9.79	10.86	4.70	81.24	0.40	18.17
7.	Dry matter content (%)	8.12	6.25-12.38	1.96	2.01	17.25	17.46	2.67	97.66	2.85	35.13
8.	Crude protein content (%)	6.19	4.65-8.47	0.93	0.99	15.60	16.07	3.85	94.25	1.93	31.20
9.	Green forage yield/ plant (kg)	19.588	8.76-42.55	70.99	75.04	43.01	44.22	10.27	94.60	16.88	86.18
10.	Dry matter yield/plant (kg)	1.686	0.65-4.60	1.05	1.09	60.72	61.97	12.38	96.01	2.07	122.55

The range of heritability (b. s.) varied from 81.24% (cladode thickness) to 98.31% (number of cladodes per plant). High heritability accompanied with high genetic advance as percentage of mean indicates that most likely the heritability is due to additive genetic effect and direct selection may be effective. This was observed in the characters *viz*. cladode length, plant width, number of cladodes per plant, plant height, cladode width, dry matter content, crude protein content and dry matter yield/plant. Paixao (2012) reported high heritability for plant height, cladode width, and cladode length. Similarly findings were also reported by Neder *et al*., (2013) for cladode length, cladode thickness, dry matter yield, cladode width, number of cladode, plant height and plant width.

The data presented in Table 4 revealed that the green forage yield/plant showed high and positive significant correlation with dry matter yield/plant (0.980, 0.969) followed by number of cladodes/plant (0.819, 0.815), dry matter content (0.816, 0.809), cladode thickness (0.813, 0.795), plant width (0.631, 0.617), cladode length (0.560, 0.561) and cladode width (0.485, 0.490) at both the genotypic and phenotypic level respectively. Other character like plant height (0.048) and crude protein content (0.048) showed positive correlation with the green forage yield but not significant at the genotypic level. Earlier Soni *et al*., (2015) reported that green forage yield significantly correlated with cladode length, cladode width, cladode thickness and number of cladodes. Amorim *et al*., (2015) reported significant correlation between plant height, plant width, number of cladodes, dry matter yield and fresh matter yield. Alves *et al*., (2016) reported significant correlation of cladode dry

TABLE 4
Estimates of genotypic (above diagonal) and phenotype correlation coefficients (below diagonal) among green forage yield /plant (kg) and nine yield contributing characters in thirty four forage cactus genotypes

Character	Plant height (cm)	Plant width (cm)	No. of cladodes/ plant (No.)	Cladode length (cm)	Cladode width (cm)	Cladode thickness (cm)	Dry matter content (%)	Crude protein content (%)	Dry matter yield/ (kg)	Green forage yield/ plant (kg)
Plant height (cm)	**1.000**	0.194	0.024	0.058	-0.425	0.188	0.001	0.502**	-0.03	0.048
Plant width (cm)	0.186	**1.000**	0.633**	0.332**	0.138	0.496**	0.485**	0.065	0.622**	0.631**
Number of cladodes /plant	0.04	0.625**	**1.000**	0.353**	0.1	0.595**	0.721**	0.119	0.848**	0.819**
Cladode length (cm)	0.093	0.315**	0.353**	**1.000**	0.141	0.289*	0.373**	-0.012	0.514**	0.560**
Cladode width (cm)	-0.376**	0.133	0.107	0.169	**1.000**	0.296*	0.408**	-0.179	0.484**	0.485**
Cladode thickness (cm)	0.231*	0.469**	0.580**	0.324**	0.320**	**1.000**	0.736**	0.032	0.771**	0.813**
Dry matter content (%)	0.018	0.477**	0.720**	0.372**	0.411**	0.716**	**1.000**	-0.168	0.894**	0.816**
Crude protein content (%)	0.472**	0.065	0.115	-0.022	-0.182	0.02	-0.167	**1.000**	-0.043	0.048
Dry matter yield/plant (kg)	-0.009	0.610**	0.846**	0.514**	0.488**	0.754**	0.890**	-0.044	**1.000**	0.980**
Green forage yield/ plant (kg)	0.069	0.617**	0.815**	0.561**	0.490**	0.795**	0.809**	0.044	0.969**	**1.000**

*, **Significant at 5% and 1 % levels, respectively.

TABLE 5
Estimates of genotypic direct (diagonal) and indirect effects (above and below diagonal) of seven component characters on green forage yield in thirty four forage cactus genotypes

Character	Plant height (cm)	Plant width (cm)	No. of cladodes/ plant (No.)	Cladode length (cm)	Cladode width (cm)	Cladode thickness (cm)	Dry matter yield/plant	Genotypic correlation with green forage yield/ plant (kg)
Plant height (cm)	**0.099**	0.001	0.007	0.010	-0.098	0.041	-0.011	0.048
Plant width (cm)	0.019	**0.004**	0.183	0.055	0.032	0.109	0.229	0.631**
Number of cladodes / plant	0.002	0.002	**0.290**	0.058	0.023	0.131	0.312	0.819**
Cladode length (cm)	0.006	0.001	0.102	**0.165**	0.033	0.064	0.189	0.560**
Cladode width (cm)	-0.042	0.001	0.029	0.023	**0.231**	0.065	0.178	0.485**
Cladode thickness (cm)	0.019	0.002	0.172	0.048	0.068	**0.220**	0.284	0.813**
Dry matter yield/plant (kg)	-0.003	0.002	0.246	0.085	0.112	0.170	**0.368**	0.980**

Residual effect= 0.109
Note: The characters viz., Dry matter content and Crude protein content are not considered for path analysis.

matter with cladode thickness, cladode length and cladode width. Barbosa *et al*., (2017) reported significant correlation between plant height and number of cladodes. However, plant height (0.069) and crude protein content (0.044) were positively correlated but not significant at the phenotypic level.

In present study, the characters dry matter yield/plant (0.368) showed highest direct positive effect on green forage yield/plant via indirect effect of plant width, number of cladodes/plant and cladode thickness (Table 5). Also number of cladodes/plant (0.290), cladode width (0.231) and cladode thickness (0.220) showed direct effect on green forage yield. Thus, direct selection for these characters would be helpful in crop breeding programme. Plant height and plant width has a positive direct effect on green forage yield but it was negligible. Earlier Neder *et al*., (2013) reported significant and greatest positive direct effect of number of cladode on dry matter yield. They observed low direct and indirect effect of other characters like thickness of cladodes, length of cladodes, width of cladodes, plant height and plant width on dry matter yield.

CONCLUSION

In the present investigation, out of thirty four genotypes, nine genotypes *viz*., Orelha De Elephanta

Promising genotypes

Orelha De Elephanta Maxicana **Palma grande** **IPA-90-92**

IPA-90-111 **COPENA F1** **IPA-90-156**

1280 **1296** **1294**

Maxicana, Palma grande, IPA-90-92, IPA-90-111, COPENA F1, IPA-90-156 , 1280, 1296 and 1294 were promising for green forage yield and its attribution and hence these genotypes could be further evaluated in multilocation trials. The characters dry matter yield/ plant showed highest direct positive effect on green forage yield/plant via indirect effect of plant width, number of cladodes/plant and cladode thickness. Also number of cladodes/plant, cladode width and cladode thickness showed direct effect on green forage yield. Thus, direct selection for these characters would be helpful in crop breeding programme.

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