Genetic Diversity among Accessions of Indian Spinach (*Basella spp.* L.) Based on Agro-Morphological Traits

Olalekan Ibrahim Sobowale[1,2*], Benjamin Oluwole Akinyele[2], Alexander Chukwunweike Odiyi[2], Emmanuel Oluwakayode Ajayi[3], Daniel Babasola Adewale[4] and Oreoluwa Busola Ajayi[5]

[1]Crop Improvement Division, Cocoa Research Institute of Nigeria, Ibadan, Nigeria.
[2]Department of Crop, Soil and Pest Management, Federal University of Technology Akure, Ondo State, Nigeria.
[3]National Horticultural Research Institute, P.M.B. 5432, Idi-Ishin, Jericho, Ibadan, Nigeria.
[4]Department of Crop Science and Horticulture, Federal University Oye-Ekiti, Ekiti State, Nigeria.
[5]Department of Forest Product, Development and Utilization, Forestry Research Institute of Nigeria, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. Author OIS designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors BOA, ACO, EOA, DBA and OBA managed the analyses of the study. Author OIS managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Medicinal and nutritional qualities of Indian spinach obviously make it a promising crop for food security in Africa. It exhibits high genetic diversity in its present under-exploited state; therefore, accurate assessment of the existing genetic diversity will be fundamental to its improvement. This study investigated the genetic diversity among twenty (20) accessions of Indian spinach using morphological descriptors. The field experiments were carried out at the Vegetable Research Farm of National Horticultural Research Institute (NIHORT), Ibadan, Oyo state, Nigeria during rainy

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Corresponding author: E-mail: sobolekky@hotmail.com;

seasons of 2016 and 2017. The experimental design adopted was randomized complete block design with three replicates. Data were collected on the vegetative characters, yield and on yield related characters. The data were subjected to Analysis of Variance, Principal Component Analysis and Cluster analyses. The first three principal component (PC) axes observed for year 2016 and 2017 explained 64.66% and 59.99% respectively of the total variation. The clustering method evolved groups of accessions based on similarities of morphological traits. Yield and yield related characters were highly and positively correlated with one another. Stem weight was positively correlated with leaf weight and total plant weight. Likewise, positive correlation existed between leaf weight and total plant weight.

1. INTRODUCTION

Indian spinach (*Basella* spp. L.) is an indigenous leafy vegetable which has high nutritional and medicinal value [1]. It is economically useful in medicine as diuretic, aphrodisiac, antipyretic and in the treatment of gonorrhoea, leprosy, dysentery, ulcer, and burns [2,3]. The vegetable is reported to be rich in vitamins A, E, K, C, B_2 and B_9 [4,5]. It contains micronutrients, macronutrients, phytochemicals and exhibits antioxidant properties [6,7]. Indian spinach is a good source protein, calcium, iron, moreover, the vegetable lacks tannins [8,9].

On the medicinal properties; [10] reported that the leaves and shoots of Indian spinach are used to cure boils and hot flashes in Ijesha land, south western, Nigeria. [11] reported that the leaf juice is used for treating catarrh and is applied externally to treat boils in Nepal and according to [12], Indian spinach is used for the treatment of hypertension in Lagos Nigeria. [13] gave a report that Indian spinach is used in India for curing constipation and gonorrhoea. According to [14 and 4], livestock are fed on the plant to increase milk production in East Africa and its fruit used for making dye. The red fruit juice can be used as ink and cosmetic and for colouring foods. Red forms of Indian spinach are commonly planted as ornamentals and as pot plants in Europe and North America [4].

In spite of the economic potential, nutritional and medicinal importance of Indian spinach, due attention has not been given to its improvement. Diversification in production and utilization of crops is essentially an important strategy to alleviate food insecurity [15]. This implies that genetic improvement on the crop can help reduce poverty, generate sustainable employment and provide foreign exchange. Of more than twenty leafy vegetables consumed in South-Western Nigeria, there are several reports of routine cultivation on only eight [16]. Fewer than six are actually grown for commercial purpose, while some others like Indian spinach grow more in the wild and peasant gardens. [17] described Indian spinach as a vegetable of increasing value though underutilized. [18] indicated that genetic diversity is a necessary primary procedure for rapid genetic improvement of crop species. The primary process enhances: understanding of individual accession's morpho-agronomic properties, a discovery on which trait-based selection depends. An articulate understanding of diversity of this crop is fundamental to its improvement.

2. MATERIALS AND METHODS

2.1 Experimental site and Materials

The experiment was carried out at the Vegetable Research Farm of National Horticultural Research Institute (NIHORT), Ibadan, Oyo state, Nigeria during rainy seasons of 2016 and 2017. Twenty Indian spinach accessions collected from five south western states of Nigeria were used for the study. Land preparation was done mechanically. The land preparation was by ploughing, harrowing and bed making. The field was laid out in a randomized complete block design (RCBD) with three replications. Seeds of Indian spinach were sown in the nursery and transplanted to the field four weeks later. The seeds were planted at 0.5 m x 0.5 m spacing on a plot size of 2 m x 1 m with a 1 m pathway between the plots.

2.2 Data collection

Data were collected on five plants randomly selected in the plot on various quantitative characters and the growth characters were evaluated at 6 weeks after transplanting. Data collected include: plant height (cm), number of leaves, leaf breadth (cm), leaf length (cm),

internode length (cm), stem girth (cm), petiole length (cm), number of branch, stem weight (g), leaf weight (g) and total plant weight (g).

2.3 Statistical Analysis

Data collected were subjected to the statistical analysis using Statistical Analysis Software (SAS), version 9.2, [19]. The analysis of variance (ANOVA) was done using PROC GLM and significant treatment means were separated using Duncan's Multiple Range Test (DMRT). Correlation among the studied traits was done using the Analyst option in SAS and Principal Component and Clustering Analysis was done using PROC PRINCOMP and CLUSTER in SAS.

3. RESULTS

The twenty Indian spinach accessions differed significantly ($P < 0.01$) from each other in 2016, and 2017 for the morphological traits studied as shown in Table 1 and Table 2 respectively. Mean performance of twenty Indian spinach accessions evaluated for agronomic and yield characters for 2016 and 2017 were also presented in Table 1 and Table 2 respectively.

Mean performance of the Indian spinach accessions evaluated for eleven (11) agronomic and yield characters for 2016 is shown in Table 1. OSG06 gave the highest mean values 108.00cm, 94.40, 19.34cm, 13.26cm, 7.23cm and 555g for plant height, number of leaves, leaf length, leaf breadth, internode length, and leaf weight respectively. Least values for plant height, number of leaves, leaf length, leaf breadth, internode length, and leaf weight were observed for AKR02 (45.47cm), IJB (14.31), OSG01 (9.46cm), AKR02 (5.95cm), OSG01 (2.70cm), and IBDLS03 (351.67g) respectively. Stem girth, petiole length, number of branches, stem weight and total plant weight ranged from IBDLS03 (1.00cm) to OSG01 (1.67cm), AKR02 (1.43cm) to ILF (2.82cm), IBD02 (3.40) to OSG04 (6.73), IBD03 (309.33g) to ADE02 (536.67g), IBDLS03 (683.33g) to ADE02 (1080g) respectively.

Table 2 presents the mean performance of the Indian spinach accessions evaluated for eleven (11) agronomic and yield characters for 2017. It was observed that accession OSG06 had the highest values of 8.02cm, 9.13, 1318.3g, 1230.0g and 2548.3g for internode length, number of branches, stem weight, leaf weight, and total plant weight respectively while the least values of (2.68cm) IBDLS03, (2.87) AKR02, (491.7g)

IBD03, (486.7g) IBDLS03, and (1000.0g) IBDLS03 were observed for internode length, number of branches, stem weight, leaf weight, and total plant weight respectively. IBDLS04 had the highest values of 16.33cm and 10.95cm for leaf length and leaf breadth respectively while least values of (12.39cm) IBD02 and (8.55cm) AKR02 were recorded for leaf length and leaf breadth respectively. Plant height ranged from 20.53cm for accession IBDLS04 to 254.37cm for accession IJB. Also number of leaves ranged from 34.30 for accession IBDLS04 to 195.45cm for accession IBD03. IBDLS04 had the highest value of 1.88cm for stem girth and least value of 1.35cm was observed for accession ADE01. Petiole length ranged from 2.07cm for accession IBDLS04 to 3.18cm for accession ADE03.

The eigenvalues, variance proportion of four principal components (PC) axes and the eigenvectors of eleven morphological traits for 2016 are presented in Table 3. Only four out of the sixteen PC axes had eigenvalues ≥ 1.0. The first axis accounted for 40.46% while the first three axes explained 64.66% of the total variation. The contribution of the remaining three axes were; 13.54%, 10.65%, and 8.06% for PC2, PC3, PC4 respectively. Morphological traits with character loadings equal to or greater than 0.2 were significant in their contribution to loading each PC axis. Eight agronomic and yield related characters namely plant height, number of leaves, leaf length, leaf breadth, internode length, stem weight, leaf weight and total plant weight loaded PC1. Four characters (stem girth, petiole length, number of leaves and total plant weight) were most important to PC2. Four characters (leaf length, leaf breadth, number of branches, and leaf weight) loaded PC3 and PC4 was also predominantly loaded with four characters.

Table 4 presents the eigenvalues, variance proportion of four principal component (PC) axes and the eigenvectors of eleven morphological traits for 2017. The percentage variance reduced progressively from PC1 to PC4; the percentages of the total variance within the first four PC axes were: 29.88, 16.00, 13.97 and 9.66 respectively. The eigenvalues of each of the first three PC axes were greater than 2.5 and the three explained 59.85% of the total variation.

In Table 4, morphological traits with eigenvectors ≥ 0.2 were significant in their contribution to loading each PC axis. Four characters namely internode length, stem weight, leaf weight and

total plant weight loaded PC1. Leaf length, Leaf breath, stem girth and number of branches were most important to PC2. One character, petiole length featured in PC3 and four characters; plant height, number of leaves, leaf length, and petiole length featured in PC4.

At the similarity level of 0.32, all the accessions formed a single cluster (Fig. 1). Three distinct clusters were feasible at the similarity level of 0.13. Group I had eleven accessions, II had eight accessions and group III had one accession. Fig. 1 also shows that the first linkage was formed

between IBDLS02 and IKL03 at 0.01 similarity level. The accession in cluster III had the highest values for all the characters (Table 5).

In 2017 at 0.175, the twenty accessions formed a single cluster and were classified into three distinct clusters (Fig. 2). Group I had twelve accessions, group II had seven accessions, and group III had one accessions. The first linkage was also observed between IBDLS02 and IKL03 at 0.02 similarity level (Fig. 2). Accession in cluster III had the highest values for all the characters (Table 6).
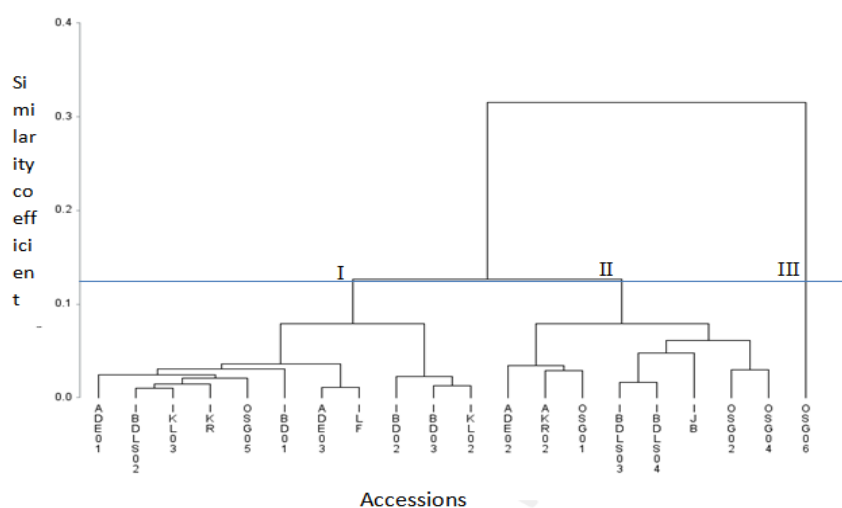

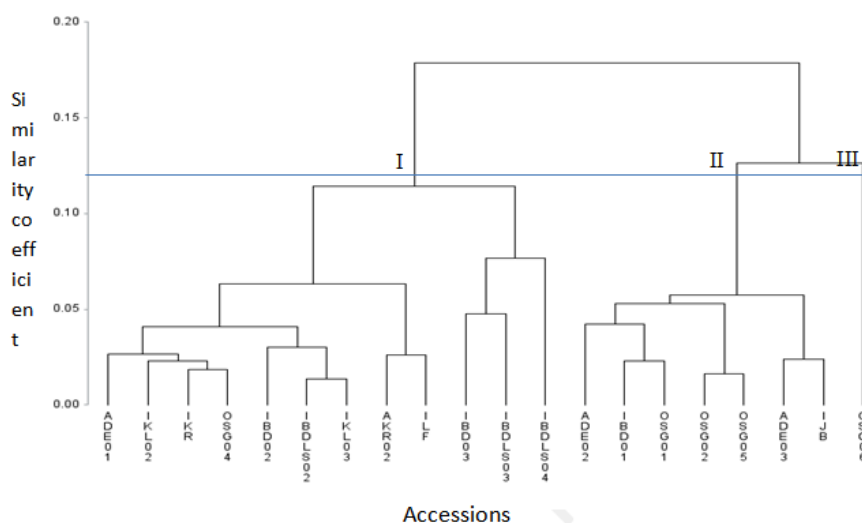**Fig. 1. Dendrogram showing grouping similarities among 20 Indian spinach accessions for phenotypic traits for 2016**

Fig. 2. Dendrogram showing grouping similarities among 20 Indian spinach accessions for phenotypic traits for 2017

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Table 1. Mean performance of twenty accessions of Indian spinach evaluated for eleven agronomic and yield traits for 2016

Accessions	Plant height	Number of leaves	Leaf length	Leaf breadth	Internode length	Stem girth	Petiole length	Number of Branch	Stem weight	Leaf weight	Total plant weight
ADE01	51.86c-g	32.03c	12.90f-h	11.30bc	3.40d-f	1.30d-f	2.00e	5.20c-f	386.33b-e	378.33d-f	764.67e-h
ADE02	47.20f-h	24.00ef	11.24h-j	8.95ef	3.62b-f	1.43b-d	1.70f	4.50ef	536.67a	543.33ab	1080.00a
ADE03	47.56f-h	18.46g	17.36a-c	11.38bc	3.76b-f	1.40b-d	2.48b	5.60b-e	420.33b-d	363.33ef	783.67e-h
AKR02	45.47h	22.41fg	13.71e-h	5.95g	3.05ef	1.20e-g	1.43g	5.33b-f	423.33b-d	425.00c-f	848.33c-g
IBD01	53.95b-e	27.01de	16.33b-d	10.06c-e	2.92f	1.17f-h	2.09de	5.33b-f	386.67b-e	458.33a-d	845.00c-g
IBD02	54.33b-d	32.10c	14.62d-g	10.68cd	3.62b-f	1.10gh	2.69a	3.40g	321.67de	386.67d-f	708.33gh
IBD03	45.68h	25.21d-f	12.58gh	10.38cd	3.49c-f	1.04gh	2.23cd	4.20fg	309.33e	448.33b-e	757.67e-h
IBDLS02	52.80b-f	33.00c	12.55gh	10.09c-e	3.31d-f	1.13gh	2.00e	5.00c-f	378.33b-e	480.00a-d	858.33c-f
IBDLS03	46.05gh	24.25ef	9.94ij	9.42de	2.97f	1.00h	1.98e	5.33b-f	331.67de	351.67f	683.33h
IBDLS04	46.36gh	29.20cd	11.64h-j	9.53de	2.84f	1.05gh	1.53fg	5.93a-c	360.00b-e	370.00ef	730.00f-h
IJB	44.02h	14.31h	16.12b-e	13.01a	2.71f	1.01h	1.54fg	5.56b-e	456.67ab	433.33c-f	890.00b-e
IKL02	49.66d-h	31.60c	12.21g-i	9.51de	3.82b-f	1.35c-e	2.33bc	4.55ef	346.67c-e	493.33a-c	840.00c-g
IKL03	55.90bc	32.83c	15.96b-e	8.68ef	4.60bc	1.35c-e	2.11de	5.00c-f	461.67ab	500.00a-c	961.67a-d
IKR	48.54d-h	22.19fg	12.82f-h	9.75de	4.26b-d	1.52a-c	2.47b	5.75a-d	461.67ab	515.00a-c	976.67a-c
ILF	48.33e-h	26.06d-f	15.73b-e	10.64cd	4.20b-e	1.43b-d	2.82a	4.66d-f	410.00b-e	501.67a-c	830.00d-g
OSG01	58.23b	26.33d-f	9.46j	8.00f	2.70f	1.67a	1.53fg	4.66d-f	395.00b-e	436.67c-f	831.67d-g
OSG02	48.07e-h	32.77c	15.28c-f	10.58cd	3.36d-f	1.49bc	1.97e	5.06c-f	390.00b-e	505.00a-c	895.00b-e
OSG04	49.20d-h	52.47b	17.88ab	12.08ab	4.73b	1.55ab	2.24cd	6.73a	426.67b-d	415.00c-f	841.67c-g
OSG05	48.21e-h	32.50c	11.83h-j	8.79ef	2.83f	1.53ab	2.27cd	5.00c-f	401.67b-e	381.67d-f	783.33e-h
OSG06	108.00a	94.40a	19.34a	13.26a	7.23a	1.51a-c	2.50b	6.33ab	448.33a-c	555.00a	1003.33ab
F.sig	***	***	***	***	***	***	***	***	***	***	***

Means followed by the same letter(s) are not significantly different according to DMRT (P<0.05)
*, **, *** - Significant at P≤ 0.5, 0.1, and 0.01

Table 2. Mean performance of twenty accessions of Indian spinach evaluated for eleven agronomic and yield traits for 2017

Accessions	Plant height	Number of leaves	Leaf length	Leaf breadth	Internode length	Stem girth	Petiole length	Number of Branch	Stem weight	Leaf weight	Total plant weight
ADE01	50.09n	85.73j	14.16a-h	10.25a-c	4.57f-j	1.35e	2.94ab	5.67c-f	851.3b-d	687.0b-e	1538.3b-f
ADE02	101.72h	155.05b	13.54c-h	10.10a-d	4.80e-i	1.54b-e	2.43bc	6.38b-f	1158.3ab	920.0b	2078.3ab
ADE03	181.76d	89.07hi	15.24a-e	10.91a	6.45bc	1.53b-e	3.18a	6.37b-f	740.3cd	666.3b-e	1406.7b-f
AKR02	214.30b	70.59l	12.96e-h	8.55d	4.05h-k	1.57b-d	2.76a-c	2.87h	833.3b-d	856.7bc	1690.0b-e
IBD01	62.80L	125.67e	14.98a-g	10.64a	3.63j-l	1.63bc	2.94ab	6.82b-e	833.3b-d	868.3bc	1701.7b-e
IBD02	56.82m	107.71f	12.39h	8.89b-d	4.58f-j	1.50c-e	2.76a-c	7.27bc	535.0cd	618.3c-e	1150.0d-f
IBD03	102.71h	195.45a	13.43d-h	10.51ab	3.87i-k	1.57b-d	2.60a-c	7.08b-d	491.7d	765.0b-d	1256.7c-f
IBDLS02	68.53k	87.79ij	12.57h	9.89a-d	3.41kl	1.63bc	3.00ab	5.39e-g	760.0b-d	860.0bc	1283.3c-f
IBDLS03	51.13n	73.80k	12.62h	10.00a-d	2.68l	1.39de	2.52a-c	5.17fg	480.0d	486.7e	1000.0f
IBDLS04	20.53o	34.30o	16.33a	10.95a	5.51c-f	1.88a	2.07c	7.80ab	495.0d	568.3de	1096.7ef
IJB	254.37a	135.67d	15.14a-e	10.95a	6.10b-d	1.53b-e	2.99ab	4.00gh	948.3a-c	773.3b-d	1721.7b-e
IKL02	93.88i	55.56n	13.92b-h	9.58a-d	6.66b	1.54b-e	2.60a-c	5.83c-f	636.7cd	866.3bc	1503.0b-f
IKL03	92.57i	91.20h	14.65a-h	9.85a-d	5.34d-g	1.54b-e	2.64a-c	3.94gh	943.3a-c	905.0b	1831.7b-d
IKR	132.09g	64.20m	15.83a-c	10.81a	4.43g-k	1.57b-d	2.76a-c	6.83b-e	948.3a-c	932.7b	1881.0bc
ILF	200.78c	73.45kl	14.63a-h	8.82cd	5.05e-h	1.53b-e	2.80ab	5.56d-f	869.0b-d	927.7b	1796.7b-d
OSG01	128.71g	99.47g	15.51a-d	10.70a	4.14h-k	1.70b	2.61a-c	6.78b-e	738.3cd	820.0b-d	1558.3b-f
OSG02	63.74l	100.87g	12.78gh	9.94a-d	3.60j-l	1.68bc	3.03ab	7.28bc	880.0b-d	905.0b	1785.0b-d
OSG04	75.18j	57.85n	12.85f-h	8.98b-d	4.83e-i	1.49c-e	2.57a-c	7.17b-d	782.3b-d	734.0b-e	1516.3b-f
OSG05	148.92f	145.50c	15.77a-c	10.62a	5.67cde	1.69bc	2.94ab	6.80b-e	768.3b-d	778.3b-d	1233.3c-f
OSG06	158.63e	135.50d	16.14ab	10.76a	8.02a	1.65bc	3.00ab	9.13a	1318.3a	1230.0a	2548.3a
F.sig	***	***	***	***	***	***	Ns	***	**	***	***

Means followed by the same letter(s) are not significantly different according to DMRT (P<0.05)
*, **, *** - Significant at P≤ 0.5, 0.1, and 0.01

Table 3. Eigen values and factor scores of characters associated with the first four principal component axes in Indian spinach for 2016

Characters	PCA1	PCA2	PCA3	PCA4
Plant height (cm)	0.2896	0.1649	-0.0937	0.0628
Number of leaves	0.2732	0.1263	0.0007	0.1332
Leaf length (cm)	0.2190	-0.0270	0.4044	0.0284
Leaf breath (cm)	0.2242	-0.1481	0.3566	-0.1540
Internode length (cm)	0.2410	-0.0691	-0.0267	-0.0989
Stem girth (cm)	0.0669	0.2379	0.0832	0.6179
Petiole length (cm)	0.1970	-0.3571	0.0281	0.2867
Number of Branches	0.1023	0.3211	0.3483	-0.1332
Stem weight (g)	0.2196	0.0321	-0.0946	-0.3085
Leaf weight (g)	0.2114	0.0320	-0.2008	-0.2433
Total plant weight (g)	0.2376	0.2507	-0.1081	0.0540
Eigenvalues	8.4972	2.8444	2.2369	1.6922
Variance Proportion (%)	40.46	13.54	10.65	8.06
Cumulative Variance (%)	40.46	54.01	64.66	72.72

Eigenvectors ≥0.2 are in bold

Table 4. Eigen values and factor scores of characters associated with the first four principal component axes in Indian spinach for 2017

Characters	PCA1	PCA2	PCA3	PCA4
Plant height (cm)	0.1385	-0.2083	0.1015	0.2082
Number of leaves	0.1111	0.0716	0.0115	0.4011
Leaf length (cm)	0.1152	0.2022	0.0241	0.3000
Leaf breath (cm)	0.1021	0.2953	0.0356	-0.0222
Internode length (cm)	0.2211	0.0137	-0.1340	-0.1308
Stem girth (cm)	0.1766	0.2456	0.1388	-0.1464
Petiole length (cm)	0.1389	0.0012	0.2778	0.3099
Number of Branches	0.1474	0.3346	-0.1828	-0.0654
Stem weight (g)	0.3067	-0.1392	-0.0139	0.0039
Leaf weight (g)	0.3090	-0.0176	-0.0892	0.0618
Total plant weight (g)	0.3099	-0.1576	-0.0728	-0.0082
Eigenvalues	7.4699	4.0005	3.4916	2.4151
Variance Proportion (%)	29.88	16.00	13.97	9.66
Cumulative Variance (%)	29.88	45.88	59.85	69.51

Eigenvectors ≥0.2 are in bold

Table 5. Intra-cluster variability of the twenty Indian spinach accessions for 2016

	Cluster groups		
Characters	I	II	III
Plant height (cm)	45.72	48.08	108.00
Number of leaves	28.45	28.22	94.40
Leaf length (cm)	14.08	13.12	19.34
Leaf breath (cm)	10.11	9.69	13.26
Internode length (cm)	3.66	3.25	7.23
Stem girth (cm)	1.30	1.30	1.51
Petiole length (cm)	2.32	1.74	2.50
Number of Branches	4.88	5.39	6.33
Stem weight (g)	389.49	415.00	448.33
Leaf weight (g)	446.06	435.00	555.00
Total plant weight (g)	828.12	850.00	1003.33
Cluster Population	11	8	1

The result of phenotypic correlation coefficient among eleven characters of Indian spinach accessions for 2016 is presented in Table 7. Plant height had positive correlation with number of leaves, leaf length, and internode length (r = 0.90, 0.44, 0.80); number of leaves was positively correlated with leaf length, leaf breadth, and internode length (r = 0.49, 0.44, 0.84); and leaf length had a positive correlation with leaf breadth, internode length (r = 0.63, 0.63). A positive correlation existed between leaf breadth and internode length (r = 0.47) and likewise between internode length and leaf weight (r =0.54). Stem girth had positive correlation with stem weight and total plant weight (r = 0.48, 0.47); stem weight had a positive correlation with leaf weight and total plant weight (r = 0.51, 0.85); and leaf weight was also positively correlated with total plant weight (r = 0.86).

Table 8 presents the phenotypic correlation coefficient among eleven characters of *basella* accessions for 2017. Leaf length had positive correlation with leaf breadth, internode length and stem girth (r = 0.70, 0.59, 0.49). Stem weight was positively correlated with leaf weight and total plant weight (r = 0.82, 0.94). Positive correlation existed between leaf weight and total plant weight (r = 0.89).

4. DISCUSSION

The success of any breeding program depends on the variations in the genetic resource. The greater the genetic variability the better would be the chances of success to be achieved through selection. The significant mean squares obtained from the analysis of variance for the accessions

suggested that at least two Indian spinach accessions will be different for all the characters evaluated, indicating the possibility for selection. Earlier studies on genetic variability in Indian spinach showed the presence of wide range of variability in both agronomic and qualitative traits for considerable scope for improvement in Indian spinach [20].

[20] reported that wide range of variation observed in most of the characters like branch number, leaf number, leaf weight, stem weight and total plant weight can form a basis for effective selection of superior lines in Indian spinach. Similarly, such quantitative characters were observed to be important for characterization of Indian spinach species in the current study. The variability observed among the Indian spinach accessions suggested that selecting for these characters will have impact on the genetic improvement of this crop. However, the exploitation of these plant characters in the breeding program of *Basella spp* will be enhanced by understanding the extent of variability existing for these traits and genetic components that govern their expression.

Principal component analysis confirmed the pattern of character co-variation among the accessions or genotype studied. In this study, different characters contributed differently to the total variation as indicated by their character loadings and weight of loadings in the four PC axes. All the characters had significant contributions to the variation among the twenty accessions of Indian spinach in 2016. Also for the accessions for 2017, all the characters contributed significantly to the observed variation. All these characters contributed

Table 6. Intra-cluster variability of the twenty Indian spinach accessions for 2017

	Cluster groups		
Characters	**I**	**II**	**III**
Plant height (cm)	96.55	134.57	158.63
Number of leaves	83.14	121.61	135.50
Leaf length (cm)	13.86	14.71	16.14
Leaf breath (cm)	9.76	10.55	10.76
Internode length(cm)	4.58	4.91	8.02
Stem girth (cm)	1.55	1.61	1.65
Petiole length (cm)	2.67	2.87	3.00
Number of Branches	5.88	7.32	9.13
Stem weight (g)	718.83	866.69	1318.00
Leaf weight (g)	767.31	818.74	1230.00
Total plant weight (g)	1461.98	1640.72	2548.30
Cluster Population	12	7	1

Table 7. Phenotypic correlation coefficient among eleven quantitative characters of Indian spinach accessions for 2016

Characters	PH	NL	LL	LB	IntL	SG	PtL	NBr	SWt	LWt	TPWt
PH		0.90***	0.44*	0.38	0.80***	0.30	0.27	0.28	0.17	0.42	0.36
NL			0.49*	0.44*	0.84***	0.34	0.31	0.41	0.10	0.35	0.28
LL				0.63**	0.63**	0.15	0.43	0.43	0.28	0.24	0.27
LB					0.47*	-0.03	0.41	0.34	0.03	0.07	0.05
IntL						0.40	0.54*	0.36	0.32	0.54**	0.49
SG							0.23	0.21	0.48*	0.39	0.47*
PtL								-0.15	-0.17	0.16	-0.07
NBr									0.37	-0.03	0.21
SWt										0.51*	0.85***
LWt											0.86***
TPWt											

NB: PH- Plant height, NL- Number of leaves, LL-Leaf length, LB-Leave breath, Intl-Internode length, SG- Stem girth, PtL- Petiole length, NBr- Number of branches, Swt- stem weight, Lwt- leave weight, TPwt- Total Plant weight

Table 8. Phenotypic correlation coefficient among eleven quantitative characters of Indian spinach accessions for 2017

Characters	PH	NL	LL	LB	IntL	VG	PtL	NBr	SWt	LWt	TPWt
PH		0.21	0.31	0.01	0.42	-0.07	0.43	-0.38	0.41	0.37	0.40
NL			0.01	0.32	0.03	-0.01	0.27	0.18	0.24	0.27	0.21
LL				0.70***	0.59**	0.49*	0.01	0.30	0.30	0.26	0.30
LB					0.25	0.37	0.10	0.36	0.12	0.02	0.07
IntL						0.16	0.15	0.25	0.42	0.39	0.44
VG							-0.23	0.41	-0.01	0.21	0.02
PtL								-0.07	0.38	0.33	0.27
NBr									0.04	0.16	0.11
SWt										0.82***	0.94***
LWt											0.89***
TPWt											

NB: PH- Plant height, NL- Number of leaves, LL-Leaf length, LB-Leave breath, Intl-Internode length, SG- Stem girth, PtL- Petiole length, NBr- Number of branches, Swt- stem weight, Lwt- leave weight, TPwt- Total Plant weight

effectively to the total variation within the tested accessions, implying that they are important in the classification of Indian spinach species. The result of the principal component analysis showed that different characters contributed differently to the total variation as indicated by eigen vectors and their factor scores on the different principal axes. As indicated by the eigen value for the two years, internode length, stem weight, leaf weight and total plant weight associated with the most discriminating principal component, the first principal axis (PC1), were of great importance in distinguishing the Indian spinach population. The wide range of variability observed along the PC1 further confirms the discriminating ability of the axis. Other characters including plant height, number of leaves, leaf length, leaf breadth, stem girth, number of branches, and petiole length loaded in PC2, PC3 and PC4.

Knowledge of correlations among characters is useful in designing an effective breeding programme for any crop. The mutual association among characters is often expressed by the phenotypic, genotypic and environmental correlation [21]. In this study, some of the agronomic and yield characters were positively correlated with one another. The implication of this is that selection or breeding for any of the characters is invariably selecting or breeding for others.

5. CONCLUSIONS

The essence of diversity studies in crop species is to reveal variations and its pattern within the crop's germplasm. The product of the assessments therefore becomes the material(s) for crop improvement. In this study, analysis of variance, Duncan's multiple range test, principal component and cluster analyses, have been used to assess Indian spinach population and group them in a more reliable way using quantitative characters. The quantitative characters have been useful as they tend to bring accessions that are genetically similar together thus reducing the number of accessions to a manageable number for a breeding programme.

The twenty accessions differ from each other based on the studied quantitative characters. Phenotypic and genetic variability exists among the twenty accessions of Indian spinach thus creating a platform for eventual selection program. ADE02 is best for 2016, while OSG06

is best for 2017. ADE02 and OSG06 were identified as the most suitable for stem weight, leaf weight and total plant weight in the agro-climatic region used in the study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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