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Characterizing the Agro-morphological Diversity of *Corchorus olitorius* L. Accessions in Botswana

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Authors' contributions

This work was carried out in collaboration among all authors. Author SBP designed the study, performed the statistical analysis, wrote the protocol, managed literature searches and wrote the first draft of the manuscript. Authors GM, JA, ST and GH read, corrected, and approved the final manuscript.

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ABSTRACT

Aim: To evaluate the genetic diversity of the local and exotic accessions of this important crop.
Study Design: The experiment was laid in a Random Complete Block Design (RCBD).
Place and Duration of the Study: The pot experiment was carried in a greenhouse at the Botswana University of Agriculture and Natural Resources, BUAN, Botswana. Study was conducted during January - May 2022.

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Methodology: The 49 accessions were planted in plastic bags in replications -. In each pot four seeds were sown and after emergence thinned to two plants per pot. The morphological characteristics were measured and recorded based on quantitative and qualitative traits following the International Board of Plant Genetic Resources (IPBGR) descriptors for *Corchorus* spp*.*

Results: Results from the analysis of variance, simple correlation and multivariate analysis demonstrated high variation among the studied accessions. Accessions such as Bafia, Aziga, ExCameroon, Local big leaves, TOT6684, MLJM4, MLJM5, SUD2, SUD3 had the highest fresh leaf biomass compared to other accessions and could be used as potential parental lines for improvement in leaf yield. Amongst the studied accessions, Delele2, Delele3, Panda and Panda1 (all from Botswana) had few numbers of days to 50% flowering, therefore can be selected for early maturity, a mechanism that most of plants used to escape the abiotic stress. Significant correlation between the leaf yield and related attributes indicated the potential accessions to use for foliage yield improvement. The principal component analysis results revealed that variations in the accessions and the cluster analysis grouped the accessions based on similarities of the morphological characters and to limited extent on their geographical origin.

Conclusions: Significant variations were found among all the accessions used in this experiment for the studied morphological characters indicating the extent of genetic variability present among them. Irrespective of origins, more diversity was observed for all the traits in the studied accessions.

Keywords: Botswana; multivariate analysis; variability; leaf yield; seed yield; early maturity.

1. INTRODUCTION

Corchorus L*. species* commonly referred to as Jute belongs to the family Tiliaceae. The genus contains 40 species occurred throughout the tropics and 30 species are found in Africa and 4 species in Nigeria [1,2]. It is commonly known with different names ie. Egyptian spinach, bush okra, Jew's mallow, and jute while the local name in Botswana is Delele. *Corchorus* species have been reported to be extremely variable morphologically, especially in the vegetative parts like leaves [2]. The genus *Corchorus* is comprised of annual or short-lived perennial herbs and shrubs with many agriculturally useful species [3]. It is a multi-purpose plant used as a source of fiber as well as for medicinal purpose in many parts of the world and most importantly as an indigenous leafy vegetable [28].

Indigenous leafy vegetables forms are as an important source of food in both urban and rural areas, their utilization is, however, limited by low yields [4, 28]. *Corchorus species* (Jew's mallow) like other African leafy vegetables, serves as an affordable source of good quality nutrition for people in rural and urban areas [4]. Nutritionally, *Corchorus olitorius* leaves are rich in beta-carotene, iron, calcium, vitamin C, A, E, proteins, sodium, and folic acid [5]. The leaves produce mucilage when cooked, a feature that enables it to be used in sauces to accompany starchy foods [3]. Jew's mallow is increasingly recognized as a possible contributor of micronutrients and bioactive compounds [6]. The leaves possess an abundance of antioxidant compounds associated with diuretic, antimicrobial antitumor, anti-obesity and gastro protective properties [7]. Research has shown that roots, barks, leaves and seeds of *Corchorus olitorius* contain flavonoids, cardiac glycosides, fatty acids, triterpenoids, polysaccharides and phenols [8,5,6].

Previous studies confirmed different benefits of Jew's mallow and is reported to be of high socio-economic benefit in some countries that are cultivating it. [9]. High genetic variability that enables it to be cultivated in different parts of the world has been reported [10]. Therefore, efforts must be channeled towards selection of promising genotypes adapted to the local climatic conditions and involve them in breeding programs for improvement of appealing or attractive characters [11]. One important characteristic that facilitates production is the ability of the available genotypes to produce increased amounts of biomass and leaves as well as increased seed yield for its continual propagation [12].

Genetic diversity assessment is important in the selection of genotypes for plant improvement because the estimates of genetic similarities and distances among genotypes are needed to select parental lines to be used in breeding programs [12]. Selection of genotypes for breeding programs, the initial description and classification of germplasm is used for characterization [13]. Morphological traits are the first genetic markers used in germplasm characterization despite having some limitations. They provide a simple way of quantifying the genetic differences while assessing performance of genotype under normal growing environment [14, 31]. The initial step towards crop improvement and domestication is characterization of genetic diversity among accessions of different germplasm by using phenotypic traits.

Domestication of *Corchorus olitorius* complemented its introduction as a vegetable in agriculture since vegetable production is a principal undertaking in Botswana. In the area of vegetable production, therefore there is a need to incorporate climate resilient crops into available arable production to provide an alternative source of leafy vegetable for the poor rural communities in Botswana. *Corchorus olitorius* is a potential crop for this purpose as it flourishes with the first rains in marginal lands or in cultivated crops as volunteer plants. Despite this potential, very little research has been done in Botswana on this crop, and there is little documentation on aspects like the genotype diversity in terms of morphological characteristics. Thus, characterization of available accessions to document the important agro-morphological information that will guide acceptance, breeding, cultivation, and consumption of the crop is needed hence this study. The objective of the study was to assess the agro-morphological divergence of 49 accessions of *Corchorus olitorius.*

2. MATERIALS AND METHODS

2.1 Experimental site

The pot experiment was carried in a greenhouse at the Botswana University of Agriculture and Natural Resources, BUAN, Faculty of Agriculture, Department of Crop and Soil Sciences, Botswana. The soil used was well drained sandy loam.

2.2 Plant Material

Of the 49 *Corchorus olitorius* accessions used in the study, 9 were sourced from the Botswana National Genetic Resource Centre (BNGRC), Botswana and 40 from the World Vegetable Centre, Regional Gene Bank, Tanzania. Seeds were sown in 5 litres plastic pots in the greenhouse. Seeds were subjected to dormancy relief by soaking in hot water at 90˚C for 5 minutes [15]. They were then air dried and planted immediately. An information of the accessions under study is given in the Table 1 below:

2.3 Experimental Design and Planting

The 49 accessions were planted in plastic bags and laid in a Random Complete Block Design (RCBD) with three replications. Blocking in the greenhouse was done against temperature (the wet wall side was cooler, and the temperature increased towards the extractor fans). Before planting, all pots were watered to field capacity. Four seeds were sown at 2cm depth because of their small size and watered thereafter. The seedlings were later thinned to two per pot two weeks after emergence. The plants were watered to field capacity thrice a week.

2.3.1 Agronomic practices

All crop management practices were carried out throughout the growing season in all the pots. These included weekly addition/ replacement of the soil in the pots to improve soil drainage, irrigation was done after every 2 days, and the plants were foliar fed using Multi feed [19:8:16] (43) that contains the following nutrients [N (193g/kg), P (83g/kg), K (158g/kg), S (6.1g/kg), Mg (4.6g/kg), Zn (700mg/kg), B (1054mg/kg), Mo (63mg/kg), Fe (751mg/kg), Mn (273mg/kg) and Cu (75mg/kg)] at the rate of 5 gram per 2 litres water. The foliar application was done 3 weeks after planting to address the deficiency of both major and minor elements in the soil. Weeds were uprooted by hand manually whenever observed.

2.4 Morphological Data Collection

The morphological characteristics were measured and recorded on quantitative and qualitative traits following the International Board of Plant Genetic Resources (IPBGR) descriptors for *Corchorus spp* (AVRDC, Genetic Resources and seed unit, 2008). Morphological parameters were measured from seedling stage until maturity stage. The 19 quantitative and 13 qualitative morphological traits assessed are presented in Table 2.

2.5 Data Analysis

2.5.1 Agro -morphological data analysis

The data collected was subjected to analysis of variance (ANOVA) using the Statistical Analysis

System (SAS) software version 9.1 program [29]. Treatment means were separated using the Least Significant Difference (LSD) at *P* = 0.05. A simple description by analyzing frequency or proportion of different variables shown by the studied accessions was performed for the qualitative data. Principal component analysis (PCA) and cluster analysis were performed and used to discriminate as well as to group the 49 accessions. The PCA was performed using the mean value of each quantitative trait for each accession using SAS software [30]. The cluster analysis using unweighted pair group method with arithmetic mean UPGMA was carried out for all the measured quantitative and observed qualitative traits to generate dendrogram of the studied accessions based on their phenotypic relationship using PAST3 software 2.17 with some modifications. Pearson's correlation coefficients were used to decide on the relationship between the traits. Descriptive statistical measures of mean and coefficient of variation were used to estimate variability amongst the quantitative traits of *Corchorus olitorius*.

Table 1. List of *Corchorus* accessions and their country of origin

ACCESSION	COUNTRY OF ORIGIN	ACCESSION	COUNTRY OF ORIGIN
TOT 4316	Bangladesh	TOT 6683	Philipines
TOT 4713	Bangladesh	TOT 6684	Philipines
TOT 4721	Bangladesh	SUD1	Sudan
TOT 4670	Bangladesh	SUD2	Sudan
AZIGA	Cameroon	SUD3	Sudan
BAFIA	Cameroon	SUD4	Sudan
EXCAMEROON	Cameroon	ES	Tanzania
TOT 6430	Cameroon	HS	Tanzania
TOT 5876	Japan	MIX	Uganda
IP1	Kenya	UG-JM-1	Uganda
IP 10	Kenya	UG-JM-2	Uganda
1P 2	Kenya	UG-JM-13	Uganda
IP 4	Kenya	TOT 4879	USA
IP 5	Kenya	TOT 6278	Vietnam
TOT 6426	Kenya	ExZIM	Zimbabwe
ExMALAWI	Malawi	MSB054	Botswana
GKK-10	Malawi	MSB072	Botswana
ML-JM-14	Malawi	MSB082	Botswana
ML-JM-12	Malawi	MSB546	Botswana
ML-JM-4	Malawi	DELELE1	Botswana
ML-JM-3	Malawi	DELELE2	Botswana
ML-JM-2	Malawi	DELELE3	Botswana
ML-JM-5	Malawi	PANDA	Botswana
ML-JM-13	Malawi	PANDA1	Botswana
LOCAL LEAVE	Mali		

Table 2. List of the descriptors and their descriptions as per the IPBGR descriptors for *Corchorus* spp (2008)

Character/variable	Description/measurement
1. Plant height (PH)	Height of the plant measured at ground surface at 50%
2. Fresh leaves	flowering.
3. Leaf length (LL)	Weight of the fresh leaves after every harvest (g)
4. Leaf width (LW)	Leaf blade length excluding petiole length (cm)
5. Leaf length-width ratio (LWR)	Mature leaf width measured at widest point (cm)
6. Petiole length (PL)	The ratio of leaf length to leaf width.
7. Days to 50% flowering (50 FLR	Length of leaf stalk (cm)
8. Number of primary branches (PB)	Number of days from sowing to 50% flowering
9. Number of secondary branches	Number of branches from main stem
(SB)	Number of branches from the secondary stem

Character/variable	Description/measurement
10. Plant canopy (PC)	Plant width taken at widest point (cm)
11. Flower diameter (FD)	The width of an open flower (mm)
12. Pedicel length (PEDL)	The stalk of the flower (mm)
13. Fruit length (FL)	Length of mature fruit excluding the pedicel (mm or cm)
14. Days to first mature pods (DMP	Number of days from sowing to first mature pod
15. Number of leaves (NL)	Counted from individual plant during flowering.
16. Biomass yield (BY)	Total weight of the plant above the ground surface (g)
17. Number of pods/plant (NPP)	Counted from individual plant at maturity stage.
18. Weight of 1000 seeds (W1000S)	Measured in weighing balance after counting (g).
19. Seeds per pod (SP)	Counted from individual pod.
20. Stem colour (ST)	1: Light green, 2: green, 3: purplish green
21. Leaf colour (LC)	1: Light green, 2: green, 3: dark green, 4: purple, 5: d/ppl
22. Leaf lobe (LL)	0: Absent, 1: present
23. Setae (S)	1: Small, 2: large
24. Leaf shape (LS)	1: Ovate, 2: elliptical, 3: cordate, 4: palmate
25. Leaf base (LB)	1: Rounded, 2: sagittate, 3: acute
26. Leaf apex (LA)	1: Acuminate, 2: caudate, 3: acute, 4: palmate
27 Leaf margin (LM)	1: Coarsely serrate, 2: cleft, 3: double serrate, 4: finely
28 Stem pattern (SP)	serrate, 5: crenate
29. Stipule colour (SC)	1: erect, 2: semi-erect
30. Petiole colour (PETC)	1: Green, 2: green stipule with dark red base, 3: light
31 Fruit shape (FS)	purple
32. Fruit colour (FRC	1: Green, 2: green with dark red base, 3: purple
	1: Globule, 2: long pod, 3: round pod
	1: Pale brown, 2: brown, 3: brown

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1. Qualitative morphological characters

During the vegetative growth stage, light green stem was dominant (34.69%) followed by light brown (30.62%), green (24.49%) and only a few (10.20%) had purple coloured stem (Table 3). The purple-coloured stem comprised of TOT6278, TOT4713, Panda, Panda1 and Delele3 accessions. Two different leaf colours were observed as green and dark green. The green coloured leaves occurred frequently (77.55%) compared to the dark green coloured (22.45%). The presence of leaf lobe was only observed in 14.29% of the accessions including Big local leaves, EXMalawi, TOT4670, ML-JM2, ML-JM4, Ml-JM3 and UG-JM1. These accessions with leaf lobes were characterized by palmate leaf shape and the leaf margins, which are finely serrated. The remaining 85.71% accessions had no leaf lobes. Ovate, elliptical, palmate, and cordate leaf shapes were observed in 65.31%, 31.37%, 12.24% and 4.08 %, respectively. Only two accessions; TOT6684 and Big local leaves had the cordate leaf shape.

There was a little variation displayed by the stem pattern and the leaf margins, where 87.76% were erect stemmed while 12.24% was semi-erect and it included six accessions all from Botswana: Panda, Panda1, Delele1, Delelee2, Delele3 and MSB072. Nearly 65.30% of the observed accessions were finely serrated, 24.49% were coarsely serrated and only 10.50% were double serrated which comprised of ML-JM2, ML-JM3, ML-JM4 all from Malawi and TOT4670 accessions from Bangladesh. At maturity stage, 91.84% of the accessions were characterized by long fruit shape, and the remaining accessions (8.16%) had round (TOT4713 and TOT6278 accessions), and globule fruits (TOT6684 and Bafia accessions). Amongst these fruits, only 4.08% (TOT4713 and TOT6278 accessions) was characterized by dark brown coloured fruits while 95.92% were brown coloured at physiological maturity.

3.1.2 Quantitative morphological traits

There was a significant variation in vegetative and reproductive characters. The results of the descriptive analysis (mean, minimum, maximum, coefficient of variance and standard deviation) were used to assess variation within each of the 21 measured traits (Table 4). The fresh leaves mass ranged from 6.97g to 41.49 g per plant.

There were differences amongst the accessions based on leaf shape, leaf size and the number of leaves produced by the different accessions under study. Similarly, the number of seeds per pod per plant exhibited a wide range 26.33 to 274.33 which may be attributed to the wide range of pod length per plant ranging 0.81cm to 9.24cm (Table 4). However, this wide range of the pod length per plant may be attributed to the different pod shapes for the studied accessions. The wide range of 2 to 13 for primary branches and secondary branches per plant (0.67 to 4.67) was also observed, where different growth habits of the accessions were observed and some had bushy canopy with many primary and secondary branches, while others had small canopy with few primary and secondary branches. The number of days to 50% flowering varied from 53.33 days to 97 days. Similarly, the number of days to pod maturity range from 86.67 days to 133 days and was closely related with the number of days to 50% flowering. The accessions under study were grouped in two categories of early maturing and late maturing types. Other traits differed among the studied accessions showing significant variation amongst the accessions include leaf length width ratio, peduncle length and dry shoot weight. The traits' coefficient of variations was observed only for five traits which had coefficient of variation more than 40%. These included primary branches (46.10%), peduncle length (44.33%), 1000 seeds mass (41.94%), pod number per plant (78.28%) and petiole length (40.92%). Most traits had the coefficient of variation of < 30%, with the dry shoot weight having as low as 7.25%. These coefficients of variance showed the variation in different accessions for these traits.

3.1.2.1 Yield and yield components

Yield and yield components of *Corchorus olitorius* accessions are presented in Table 5. Number of leaves per plant was significantly different ($P \leq 0.05$) among the studied accessions with the most prominent difference between TOT 6278 from Vietnam (317.7) and MLJM3 from Malawi (166.6). Fresh leaves weight varied significantly ($P \leq 0.05$) among the accessions with Bafia from Cameroon recording the highest weight (41.58g per plant) and Delele 2 from Botswana recording the lowest value (6.96g per plant).

Table 3. Frequency distribution of some of the 13 qualitative morphological traits of Jew's mallow accessions under study

Character	Descriptors	Frequency %
Stem colour	green	24.49
	light/green	34.69
	purple	10.2
	light/brown	30.62
	green	77.55
Leaf colour	dark/green	22.45
	Absent	85.71
Leaf lobe	Present	14.29
Leaf shape	ovate	65.31
	elliptical	18.37
	cordate	4.08
	palmate	12.24
	round	8.17
Leaf margin	Double	10.2
	finely/serrate	65.3
	coarsely/serrate	24.49
Stem pattern	semi-erect	12.24
	Erect	87.76
Fruit shape	long	91.84
	Round	4.08
	Globule	4.08
Fruit colour	brown	95.92
	dark brown	4.08

Table 4. Descriptive statistics of 19 morphological quantitative traits of Jew's mallow accessions

Character	Mean ± SE	Mini	Maxi
fresh leaves	22.76 ± 1.17	6.94	41.59
dry leaves	5.23 ± 0.26	1.54	9.31
leaf number	212.15 ± 0.16	166.6	317.7
plant height	113.71 ± 1.64	56.67	169
leaf width	5.03 ± 0.16	1.86	7.81
leaf length	10.65 ± 0.29	5.37	17.86
LLW ratio	2.22 ± 0.07	1.3	3.64
petiole length	3.03 ± 0.18	0.81	9.24
pod number	16.67 ± 1.86	5.33	64.67
pod length	69.43 ± 2.46	11.33	101.8
seeds per pod	153.89 ± 6.65	26.33	274.33
1000 seeds mass	2.84 ± 0.15	0.57	5.76
penducle length	0.97 ± 0.06	0.1	1.87
flower diameter	12 ± 0.60	1.77	19.52
Days to 50% flowering	64.69 ± 1.29	53.33	97
Days to mature pod	140.55 ± 2.49	86.67	1333
Biomass	53.12 ± 0.55	44.76	60.64
primary branch	6.03 ± 0.40	2	13
secondary branch	2.61 ± 0.11	0.67	4.67

Plant height was significantly different (P ≤ 0.05) among the studied accessions with more variation between the accessions, highest values were recorded from IP1 (169cm) and ES (158cm) from Kenya and Tanzania respectively, while Delele2 (56.67cm) and Deleel3 (59.33cm) and Panda (65cm) all from Botswana, recorded the lowest values amongst all the accessions under study. Significant differences (P ≤ 0.05) were also observed in number of pods per plant with Delele3 from Botswana recording the highest (64.67) while Mix from Tanzania and Bafia recorded the lowest number of pods of 6.33 and 5.3, respectively.

Bafia recorded the lowest number of primary branches per plant (2) and IP1 from Kenya recorded the highest (13). The total number of seeds per pod ranged from 26.33 to 274.33, TOT 4713 from Bangladesh recorded the lowest value of the total number of seeds per pod while Mix from Tanzania had the highest value. Significant differences (P ≤ 0.05) were also observed in 1000 seed weight with accession TOT 6278 from Vietnam recording the highest weight of 5.76mg while there was no significant difference between Delele2, Delele3, Panda1 and Panda all from Botswana, recording the lowest values ranging from 0.57-0.84mg. Furthermore, a significant difference (P ≤ 0.05) for number of days to 50% flowering was observed between the accessions where the earliest flowering was observed in some of the accessions from Botswana, (i.e., Panda, Delele1, MSB072 and MSB054) just like HS from Tanzania and TOT4713 from Bangladesh with values ranging from 53.33-57.67days. The highest number of days to 50% flowering was observed in MLJM3, Aziga, ExCameroon, Bafia, SUD2 and SUD3 with values ranging between 76-97 days. Amongst these accessions with high values, three are from Cameroon and two are from Sudan. The accessions with the high number of days to flowering may be classified as late maturing accessions while those with the lowest days to flowering may be classified as the early maturing type.

3.1.2.2 Correlation among the quantitative morphological traits

The Pearson's correlation coefficient analysis was carried out to find the relationship among morphological traits (Table 6). The correlation matrix highlights many significant correlations both positive and negative at 5% threshold for the different characters under study. Fresh leaves weight was statistically significant (*P*<0.0001) with a very strong positive correlation with dry leaf weight (r = 0.966) and moderately positively correlated with leaf length (r = 0.66), days to 50% flowering (r = 0.583) and the flower diameter (r = 0.583). Leaf width showed moderate positive correlation with petiole length (r = 0.43). The fresh leaves were negatively correlated with leaf number (r = 0.252), pod number (r = 0.483) and primary branches (r = 0.414). Leaf number had moderate significant positive correlation with the pod number (r = 0.539); moderate significant negative correlations were further observed between leaf number and seeds per pod (r = 0.588) and pod length (r = 0.487). Similarly, pod length exhibited a significant positive correlation with seeds per pods (r = 0.638). A moderate significant negative association between pod number and pod length (r = 0.582), seeds per pod (r = 0.623) and (r = 0.615) for the flower diameter was observed. Furthermore, a very strong positive correlation between the dry shoot weight and fresh shoot weight was observed (r = 0.927) and a very low positive correlation with primary branches (r = 0.328).

3.1.2.2 Principal component analysis (PCA)

Principal component analysis (PCA) was carried out to reveal the relationship between the 31 characters studied which generated 34 principal components (PC) and is presented in Table 7. The first four principal components had an eigenvalue greater than 2. These principal components accounted for 58.72% of the total variability of the morphological traits amongst the studied 49 accessions while the remaining components contributed only 21.28% of total variability for the accessions, with eigenvalue less than 2 but greater than 1. The fresh leaves weight, dry leaves weight, leaf width and flower diameter loaded high in principal component 1 (PC1) and accounted for 23.4% of the total variation of the samples with an eigenvalue of 7.96. The highest positive loading was associated with leaf width (0.31), leaf fresh weight (0.30), dry leaves weight (0.28), and the flower diameter (0.26). The component characterizes accessions with good performance for each of these characters. The second principal component (PC2) accounted for 14.95% of the total morphological variation amongst the accession with the highest positive loading exhibited by fruit shape (0.35), leaf number (0.28) and leaf colour (0.27). The third principal component (PC3) accounted for 11.19% of the total variation with 3.806 eigenvalue. Traits such as primary branches (0.30) and secondary branches (0.33) loaded more in this component. The fourth principal component (PC4) accounted only 9.19% of the total variation with 3.123 eigenvalue. Leaf length (0.31) and stem colour (0.29) loaded the highest. Generally, PC1, PC2 and PC3 constituted 49.54% of the total morphological variation with mostly the vegetative related traits. This indicated that these traits could be used to classify the accessions under study.

3.1.2.4 Morphological cluster analysis

A dendrogram for complete linkage cluster analysis of qualitative and quantitative traits was generated for the 49 accessions and is presented in Fig. 1. The results indicated that the accessions were assigned to four major groups. Cluster 1 contained only one accession, SUD3 from Sudan. It is characterized by green leaves and stem, with semi erect stem pattern. The green leaves have an acute leaf base and apex with coarsely serrated margin. The pods are long and brown in colour. This accession was the third best in fresh leaves biomass (Table 5), but fewer branches compared to the accessions under study.

Cluster 2 contained 15 accessions; Botswana (4), Malawi (3), Sudan, Uganda, Vietnam, Tanzania, Bangladesh, USA, Kenya, and Mali having only one accession each. The accessions were largely characterized by green stem, long brown pods with semi erect stem. However, exceptions were accessions from Vietnam (TOT 6278) and Bangladesh TOT 4713) which have purple stem and round dark brown pods with erect stem. Their leaf base was acute and caudate leaf apex with coarsely serrated margins. The accessions from Botswana, had the lowest fresh leaves biomass (Table 5). These accessions have similar leaf number with fewer days to 50% flowering than the rest of the accessions under this cluster.

Cluster 3 contained 16 accessions: Botswana (5), Cameroon (2), Malawi (2), Tanzania (2), Bangladesh (2), Japan (1), Philippines (1), and Uganda (1). Accessions from Botswana had similar traits being green semi erect stem with green leaves and the petiole were light green and having long brown pods. Accessions from Malawi, Tanzania, Japan, Bangladesh, and Uganda were characterized by acute leaf base and leaf apex with finely serrated margin. Green semi erect stem with long brown pods while the Philippines accession was an exception with an erect stem. Aziga from Cameroon was the only exception in this cluster with globule pod shape compared to the rest of the accessions in this cluster that had long pods. The two accessions from Cameroon (Ex Cameroon and Aziga) were characterized by high fresh leaves biomass and number of days to 50% flowering (Table 5). The Botswana accessions quantitative traits such as fresh leaf biomass, number of leaves and number of days to 50% flowering were not significantly different at ($P \leq 0.05$).

Table 5. Quantitative yield and yield contributing traits of Jew's mallow accessions

ACC	Lfn	frsl	Height	Pribran	Pdn	s/pod	1000seds	Dysflw
SU3	240^{bc}	38.7^{ab}	135.33^{a-d}	3.33^{e-g}	7.67^{gh}	211.67^{ad}	2.52^{c-j}	76^{c-f}
TOT4713	345^{ab}	22.68^{e-l}	80.00^{d-g}	9^{a-e}	35^{cd}	26.33^{k}	3.74^{b-f}	59^{k-p}
TOT6278	371.7^{a}	15.02^{kl}	133.00^{a-g}	9.33^{a-d}	50.67^{ab}	34.33^{jk}	5.76^{a}	60.67^{j-p}
MLJM3	166.6^{c}	27.72^{a-k}	116.00^{ag}	4.67^{c-g}	8.3^{f-h}	79.67^{h-k}	2.57^{c-i}	97^{a}
DELELE2	301.8^{a-c}	6.96^{n}	56.67^{g}	3^{e-g}	30.67^{de}	59^{i-k}	0.57^{k}	58.67^{k-p}
DELELE3	300^{a-c}	12.48^{k-n}	59.33^{gf}	6.67^{b-g}	64.67^{a}	101.33^{fk}	0.58^{k}	57.67^{l-p}
PANDA1	255^{a-c}	10.14^{mn}	78.33^{dg}	6.67^{b-g}	47.33^{bc}	96.67^{h-k}	0.84^{k}	53.33^{p}
PANDA	300^{a-c}	12.12^{l-n}	65.00^{e-g}	5.33^{c-g}	56.33^{ab}	97^{h-k}	0.62^{k}	59.33^{k-p}
ES	212.6^{c}	19.74^{k-n}	158.00^{ab}	5^{c-g}	10.33^{f-h}	184^{a-g}	4.59^{ab}	64.67^{g-n}
TOT4879	270^{a-c}	14.76^{i-n}	122.67^{a-g}	9.33^{a-d}	12^{f-h}	181^{a-g}	2.48^{c-j}	60.67^{j-p}
IP10	258.3^{a-c}	18.06^{h-l}	107.33^{a-g}	4^{c-g}	5.67^{h}	197^{a-e}	4.01^{b-d}	70.33^{d-i}
UGJM13	270^{a-c}	19.44^{k-n}	114.67^{a-g}	5.67^{c-g}	7.67^{gh}	196.67^{ae}	3.26^{b-g}	61.33^{j-p}
MLJM12	238.2^{bc}	20.7^{e-l}	121.67^{a-g}	6.67^{b-g}	8.33^{f-h}	193.67^{af}	3.76^{b-e}	62.33^{i-p}
MLJM13	249.9^{a-c}	22.98^{e-l}	118.33^{a-g}	8^{a-g}	11^{f-h}	192.67^{af}	2.92^{b-i}	60^{k-p}
LOCAL	226.8^{bc}	26.64^{a-k}	84.3^{d-g}	4.33^{c-g}	13^{f-h}	199.67^{ae}	3.96^{b-d}	68.67^{d-k}
SUD4	256.8^{a-c}	19.14^{k-n}	102.67^{a-g}	5^{c-g}	9^{f-h}	204^{a-d}	3.78^{b-e}	67^{e-k}
GKK10	258.3^{a-c}	22.14^{e-l}	124.67^{a-g}	6.33^{c-g}	10.33^{f-h}	218^{a-c}	3.49^{b-f}	64.33^{g-o}
CAMERON	222.3^{bc}	38.46^{a-c}	123.00^{a-g}	4.33^{c-g}	14^{f-h}	229^{ab}	3.25^{b-g}	78.33^{cd}
AZIGA	183.3^{c}	38.4^{a-c}	92.00^{b-g}	2.33^{fg}	8.3^{f-h}	115.67^{ek}	2.25^{e-k}	90.67^{ab}
MSB546	180^{c}	15.36^{kl}	96.33^{b-g}	2.67^{fg}	11.33^{f-h}	144.67^{bi}	2.05^{f-k}	60^{k-p}
DELELE1	210^{c}	15.36^{kl}	127.00^{a-f}	7^{a-g}	19.67^{e-h}	124.67^{cj}	2.55^{c-i}	56.67^{m-p}
TOT4721	255^{a-c}	22.5^{e-l}	109.33^{a-g}	5^{c-g}	17^{e-h}	138.67^{ci}	2.52^{c-j}	60.33^{j-n}
TOT4316	261.6^{a-c}	19.62^{g-l}	88.33^{b-g}	6.33^{c-g}	13^{f-h}	138^{b-i}	3.08^{b-g}	60^{k-p}
MSB082	222.3^{bc}	17.64^{kl}	110.00^{a-g}	6.67^{b-g}	21.68^{d-g}	160.33^{bh}	2.4^{d-j}	58.67^{k-p}
MSB072	200.1^{c}	19.26^{h-l}	108.67^{a-g}	2.67^{fg}	19.67^{e-h}	160.33^{bh}	2.4^{d-j}	57.33^{l-p}
MSB054	191.7^{c}	17.16^{kl}	120.33^{a-g}	5.67^{c-g}	22.67^{d-f}	154.67^{bh}	2.41^{d-j}	57.67^{l-p}
TOT5876	278.4^{a-c}	20.28^{e-l}	104.67^{b-h}	7.67^{a-g}	16^{f-h}	160.67^{bh}	2.51^{c-j}	60.67^{j-p}
HS	236.7^{bc}	19.86^{f-l}	126.33^{a-f}	3^{e-g}	7.67^{gh}	178^{b-h}	4.18^{a-c}	54.33^{op}
MLJM14	216.6^{c}	17.16^{h-l}	126.33^{a-f}	7.33^{a-g}	11^{f-h}	169^{b-h}	2.96^{b-i}	61.67^{j-p}
UGJM2	256.8^{ab}	24.72^{a-l}	107.$^{a-g}$	4^{c-g}	13.67^{f-h}	157^{b-h}	3.57^{b-f}	60^{k-p}
MIX	225.8^{c}	18.18^{kl}	114.$^{a-g}$	5.33^{c-g}	6.33^{h}	274.33^{a}	3.78^{b-e}	66.67^{f-m}
TOT6683	229.5^{c}	12.72^{k-n}	87.33^{b-g}	5^{c-g}	9^{f-h}	165^{b-h}	2.83^{c-i}	73.33^{c-g}

ACC	Lfn	frsl	Height	Pribran	Pdn	s/pod	1000seds	Dysflw
SUD2	285^{abc}	34.62^{a-g}	131.33^{a-e}	3^{e-g}	10.33^{f-h}	162.67^{bg}	1.77^{h-k}	76^{c-f}
MLJM5	211.8^{c}	34.92^{a-f}	120.33^{a-g}	4.67^{c-g}	9^{f-h}	175.67^{bg}	1.66^{h-k}	62.67^{h-p}
BAFIA	216.6^{c}	41.58^{a}	114.67^{a-g}	2^{g}	5.3^{h}	193.67^{af}	3.8^{b-e}	80.67^{bc}
MLJM4	233.4^{bc}	31.26^{a-f}	127.00^{a-f}	5.67^{c-g}	7.67^{gh}	163^{b-h}	3.57^{b-f}	57.33^{l-p}
IP1	286.8^{a-c}	16.32^{h-l}	169.00^{a}	13^{a}	14.33^{f-h}	154.33^{bh}	3.52^{b-f}	56.33^{n-p}
IP2	256.8^{a-c}	20.88^{e-l}	156.00^{a-c}	12.67^{ab}	11.64^{f-h}	163.67^{bh}	3.03^{b-i}	66^{f-m}
SUD1	234.9^{bc}	37.98^{a-d}	144.67^{a-d}	3^{e-g}	12.33^{f-h}	166.33^{bh}	2.51^{c-j}	72.67^{c-h}
TOT4670	233.4^{bc}	25.32^{a-l}	131.33^{a-e}	8^{a-g}	12.33^{f-h}	160.67^{bh}	2.91^{b-i}	64.33^{g-o}
MLJM2	245.1^{a-c}	28.68^{a-i}	139.00^{a-d}	4.33^{c-g}	9.33^{f-h}	146.33^{bi}	3.3^{b-h}	77^{cde}
IP5	279.9^{a-c}	20.88^{e-l}	97.00^{b-g}	8^{a-g}	22.67^{d-f}	148^{b-i}	2.84^{c-i}	63.33^{g-p}
TOT6426	248.4^{a-c}	13.98^{k-n}	133.334^{ae}	13^{a}	18.33^{e-h}	140.33^{bi}	2.87^{c-i}	64.67^{g-n}
EXMALAW	266.7^{a-c}	23.58^{c-l}	119.33^{a-g}	8.33^{a-f}	16^{f-h}	142.67^{bi}	4.01^{b-d}	60^{k-p}
EXZIM	296.7^{a-c}	29.52^{a-i}	139.33^{a-d}	8^{a-g}	16^{f-h}	137.93^{bi}	3.34^{b-g}	59^{k-p}
TOT6684	230.02^{bc}	35.1^{a-e}	101.67^{a-g}	2.67^{fg}	14.33^{f-h}	121.67^{dj}	1.35^{i-k}	73.33^{c-g}
TOT6430	256.8^{a-c}	19.98^{kl}	82.00^{d-g}	10^{a-c}	11.67^{f-h}	122.33^{dj}	1.66^{h-k}	72^{c-i}
UGJM1	226.8^{bc}	24.6^{a-l}	122.67^{a-g}	3^{e-g}	14.33^{f-h}	118.67^{dk}	3.46^{b-g}	63.33^{g-p}
IP4	306.6^{a-c}	27^{a-l}	144.00^{a-d}	9.67^{a-c}	10^{f-h}	119.67^{dk}	2.43^{d-j}	58.67^{k-p}

Means followed by the same letter are not significantly different according to Least Significant Difference (LSD) at P=.05 significance level. Lfn- Number of leaves per plant. Frsl- fresh leaf weight per plant. Pribra- number of primary branches per plant. Pdn- Number of pods per plant. s/pod- number of seeds per pod. 1000seds- weight of 1000 seeds. Dysflw- Number of days to 50% flowerin

Table 6. Pearson's correlation coefficient amongst the quantitative morphological traits of Jew 'mallow

	FL	DL	LN	PH	LW	LL	LWLR	PL	PDN	PDL	SDP	SDM	PNL	FLD	DYF	DYMP	FS	DS	HI	PB	SB
FL	1	0.966*	0.253	0.329	0.774*	0.657*	0.367	0.449	0.483	0.034	0.449	0.092	0.025	0.543*	0.583*	0.339	0.421	0.354	0.953*	0.444	0.097
DL		1	0.157	0.373	0.746*	0.695*	-0.323	0.431	-0.389	-0.032	0.336	0.121	0.005	0.534*	0.509*	0.327	0.469	0.412	0.976*	-0.323	-0.114
LN			1	0.051	-0.386	-0.181	0.381	-0.225	0.539*	-0.486	-0.588*	0.073	-0.245	-0.159	-0.311	-0.066	0.145	0.216	-0.226	0.475	0.018
PH				1	0.143	0.381	-0.419	0.389	0.452	0.374	0.288	0.613*	0.139	0.468	0.0007	0.11	0.544*	0.524*	0.325	0.264	0.287
LW					1	0.437	-0.739*	0.434	-0.58*	0.247	0.469	0.317	0.073	0.534*	0.504*	0.113	0.533*	0.44	0.716*	-0.277	-0.049
LL						1	0.178	0.194	-0.157	-0.039	0.319	-0.068	0.075	0.293	0.409	0.234	0.037	0.089	0.717*	-0.187	-0.039
LWLR							1	-0.436	0.715*	-0.468	-0.37	-0.526*	-0.081	-0.508*	-0.262	0.014	-0.536	-0.391	-0.286	0.124	-0.095
PL								1	-0.494	0.177	0.205	0.223	0.017	0.36	0.135	0.135	0.367	0.303	0.411	0.033	0.245
PDN									1	-0.582*	-0.622	-0.348	0.333	-0.615*	-0.395	-0.158	-0.312	-0.193	-0.387	0.187	-0.105
PDL										1	0.637*	0.247	0.319	0.32	-0.052	-0.031	0.133	0.137	-0.048	0.017	0.364
SDP											1	0.173	0.306	0.397	0.327	0.204	0.07	0.06	0.354	-0.264	0.178
SDM												1	-0.04	0.245	-0.028	-0.022	0.429	0.417	0.054	0.163	0.347
PNL													1	0.149	0.143	0.014	0.106	0.053	-0.017	0.138	0.0259
FLD														1	0.266	0.259	0.577*	0.523*	0.487	-0.027	0.083
DYF															1	0.24	0.11	-0.021	0.556*	-0.344	-0.357
DYMP																1	0.009	-0.052	0.379	-0.142	-0.108
FS																	1	0.927*	0.334	0.327	0.246
DS																		1	0.254	0.324	0.257
HI																			1	-0.381	-0.167
PB																				1	0.520*
SC																					1

*FL-fresh leaves; DL-dry leaves; HI-harvest index; PH-plant height; LN-leaf number; DYF-days to 50% flowering; DYMP-days to mature pods; LW-leaf width; LL-leaf length; LWLR-leaf width length ratio; PL-petiole length; PDN-pod number; PDL-pod length; S/POD- number of seeds per pod; 1000SEEDS- weight of 1000 seeds; PNL-peduncle length; FH-fresh shoot weight; DS-biomass. * Significant at P < 0.001*

Table 7. Eigenvalues, proportion of variance and morphological traits that contributed to the first four Principal components (PCs)

	PC1	PC2	PC3	PC4
Eigen value	7.955	5.081	3.806	3.123
Proportion of variance (%)	23.4	14.95	11.19	9.19
Cumulative variance (%)	23.4	38.34	49.54	58.72
plant height	0.19	0.09	0.24	0.19
leaf width	0.31	0.05	-0.06	-0.02
leaf length	0.15	-0.03	-0.25	0.31
leaf length width ratio	-0.26	-0.04	-0.18	0.18
petiole length	0.21	0.04	0.07	-0.05
pod number	-0.28	0.15	-0.11	0.03
pod length	0.14	-0.25	0.29	0.04
seeds per pod	0.21	-0.24	0.04	0.13
1000 seeds weight	0.13	0.19	0.26	0.1
peduncle length	0.07	-0.19	0.11	0.02
flower diameter	0.26	0.03	0.06	0.12
Days to 50% flowering	0.19	-0.01	-0.26	-0.08
Days to mature first pod	0.1	-0.01	-0.15	0.05
Biomass yield	0.17	0.23	0.2	0.08
Primary branches	-0.09	0.11	0.3	0.1
Secondary branches	0.02	0.01	0.33	0.09
Stem colour	-0.09	-0.07	0.2	0.29
leaf colour	0.08	0.27	-0.04	-0.05
leaf lobe	0.12	0.14	0.06	-0.45
seta	0	0	0	0
leaf shape	0.06	0.2	0.03	-0.42
leaf base	-0.05	-0.08	-0.1	0.33
leaf apex	0.23	-0.12	0.13	0.1
leaf margin	0	-0.2	0.06	0.02
stem pattern	-0.02	-0.21	0.18	-0.07
stipule colour	0.07	-0.32	-0.01	-0.17
fruit/pod colour	0.01	0.22	-0.04	0.24
fruit/pod shape	-0.09	0.35	-0.03	0.16

Cluster 4 was the largest with 17 accessions: Kenya (5), Malawi (4), Cameroon (2), Sudan (2), Bangladesh (1), Zimbabwe (1), Philippines (1), and Uganda (1). The cluster had accessions with both erect and semi erect stem, light green and green stem, with long brown pods. Bafia from Cameroon was an exception with globule pods, dark green leaves. Accessions from Philippines (TOT 6684) had cordate leaf shape with round base and acute leaf apex. Accessions from this cluster are all characterized by high yield with high leaf fresh biomass, leaf number (Table 5).

The data (Table 8) shows that the highest in plant height (135.33cm), number of days to 50% flowering (76days), number of days to first mature pod (133.33days), which confirmed a good relationship between these two traits, leaf width (5.5cm), leaf length (13.66cm), leaf length width ratio (2.45) and seeds per pods (211.67 seeds) were grouped Cluster 1. The accessions under this cluster can also be selected for maturity and leaf size.

Cluster 2 had the highest leaf number (273.65), pods number (24.67) and 1000 seeds weight (2.90 mg). Accessions under this cluster can be selected for seeds production as well improvement for leaf number production for those yielding low number of leaves. Cluster 3 was the highest in dry leaves weight (7.62 g), pod length (78.25 cm) and peduncle length (1.03 cm). Cluster 4 had the highest fresh leaves biomass (27.26 g), total shoot biomass (55.8g) and harvest index (0.66). Accessions under this cluster can be selected for vegetable production thus, leaf production and improvement as well as for those countries who are already cultivating Jew’s mallow for fibre production.

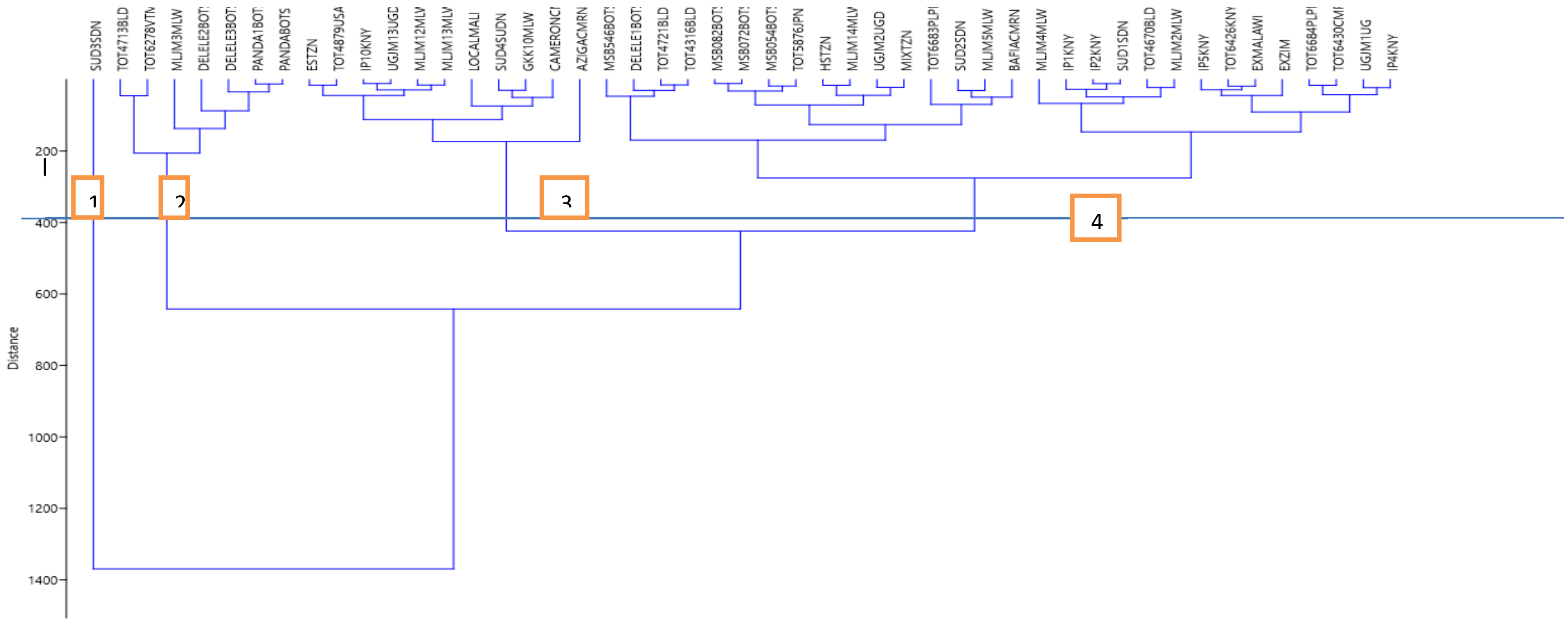

Fig. 1. Dendrogram of 49 accessions of *Corchorus olitorius* based on complete linkage clustering of 19 quantitative traits and 13 qualitative traits

Table 8. Cluster analysis based on 18 quantitative traits of *Corchorus olitorius*

	C1	C2	C3	C4
FL	26.73	17.91	26.22	27.26
DL	5.64	4.18	7.62	6.26
PH	135.33	99.86	110.37	127.76
LN	230	273.65	224.1	253.85
PB	3.33	6.13	5.08	7
DYF	76	63.73	63.79	65.72
DYMP	133.33	108.51	108.42	128.86
LW	5.5	4.51	5.07	5.41
LL	13.66	9.59	10.92	11.15
LWLR	2.45	2.41	2.02	2.1
PL	3.62	2.51	2.59	3.8
PDN	7.67	24.67	13.83	12.82
PDL	65.14	61.11	78.25	68.73
S/POD	211.67	137.22	170.81	149.27
1000SEDS	2.52	2.9	2.89	2.77
PNL	0.97	0.91	1.03	0.96
FH	11.12	9.71	11.89	14.05
DS	50.84	52.6	50.93	55.78

FL-fresh leaves; DL-dry leaves; PH-plant height; LN-leaf number; PB-primary branches; DYF-days to 50% flowering; DYMP-days to mature pods; LW-leaf width; LL-leaf length; LWLR-leaf width length ratio; PL-petiole length; PDN-pod number; PDL-pod length; S/POD- number of seeds per pod; 1000SEEDS- weight of 1000 seeds; PNL-peduncle length; FH-fresh shoot weight; DS-biomass

3.2 Discussion

3.2.1 Qualitative morphological variation

The existence of the qualitative morphological variation among the *Corchorus olitorius* accessions was revealed in this study, indicating genetic divergence amongst the accessions. Significant variation ($P \le 0.05$) was evidenced particularly in the leaf architecture traits i.e. shape, base, margin, colour, and apex. The results of this study are consistent with those of [12, 16, 17,18, 19, 32] who found some substantial variations in most of the qualitative characters studied in Jew's mallow, especially in the vegetative parts like leaves [2]. This crop is an important leafy vegetable; therefore, its vegetative architecture is significant for leaf production. In this study, 67.31% accessions were possess ovate leaf shape with 63.27% coarsely serrated margins and 79.59% acute leaf apex. Similarly, **Edmonds** [2], reported simple ovate, elliptic lanceolate or oblong leaves, margin serrated or crenate often with a pair of basal setae, usually rounded or craniates at the base and rarely truncated. Ngomuo et al [12] further reported a similar variation on the stem pattern where some accessions were either semi-erect or erect. In addition, similar findings were observed for predominant green coloration on leaf lamina (94.44%), stems (97.22%) and stipule (97.22%) on the evaluated accessions, dark green or red colour was observed in the other varieties for the same traits [17]. According to Maina et al [20], variations in stem colour, leaf shape and stipule are the most informative phenotypic variables for the assessment of *Corchorus olitorius* genotypes. To improve leaf production of Jew's mallow, the knowledge required is not only that of the diversity and genetic variability of the available germplasm but also the genetic architecture of the leaf and its components.

3.2.2 Quantitative morphological variation

Significant (P = .05) variations were observed for the quantitative morphological traits in 49 accessions under study, indicating an adequate amount of genetic variability among the Jew's mallow accessions as shown by the Descriptive statistics of 19 morphological quantitative traits as well as the yield and yield components. The accessions demonstrated high variation in number of leaves per plant, fresh leaves weight, number of branches, number of pods per plant and the number of seeds per pod. These are important aspects to consider during selection of accessions with high leaf yield. Quantitative traits like number of leaves per plant, plant height at maturity, harvest index have been identified as important discriminating traits among the Jew's mallows. [11, 19, 3, 21, 18, 11, 12]

Plant height was significantly different ($P \leq 0.05$) among the studied accessions with more variation between the accessions and ranged between 56.67cm-169cm. On the contrary, Jui et al [22] reported plant height at harvest time ranging from 2.02-3.27m and the variation could be attributed to variation in genotypes used.

It was observed that, accessions that took more days to reach 50% flowering and subsequently longer to mature, had the highest fresh leaf biomass. This could possibly be because of prolonged days to maturity translates to more days for photosynthesis, leading to higher biomass production and thus high crop yield [23]. The range of days to 50% flowering obtained under this study was 53.33 – 97 days, higher than the values reported by [11], who observed range values between 30.83-76.53 among the 40 accessions evaluated while [17] reported range of values between 41- 89days but less than those of [12, 24] who reported 52 – 110 days to 50% flowering for the 90 accessions studied.

Significant variation was also observed for number of leaves per plant with values ranging between 180-371.65. TOT6278 from Vietnam and TOT4713 from Bangladesh, Delele 2, Delele3, Panda from Botswana and IP4 from Kenya had the highest number of leaves even though their fresh leaf biomass was significantly less than those with a smaller number of leaves, possibly because the leaves were small sized, a common character with most of the local accessions. Contrary to these finding, [25] reported that, TOT 4051 had the smallest leaf area (33.33 cm2) of the five accessions with the highest fresh leaf yield but had the highest number of leaves (1089.7) compared with all other accessions in their study. A high number of leaves contributed to the high yield in leaf fresh weight of that accession. Thus, not only does leaf area contribute to leaf yield, but the number of leaves as well. Leaf area is an important trait in the selection of accessions with high leaf yield. Higher range was reported by [17] who found significant variation among the accessions with values ranging between 383 - 1235.

Results of the current study revealed that, some accessions such as TOT6278 had many leaves and highest 1000 seeds weight compared to other accessions. The above results are similar to [26] findings, who reported that a high number of leaves per plant correlated positively with high pods weight, thus a strong and positive correlation was observed between the number of leaves per plant and number of pods per plant. This could possibly be because, accessions with high number of leaves are likely to have higher photosynthesis thus higher partitioning of assimilates leading to higher seed yield. This shows that it is important to strike a balance between the seed yield and leaf yield attributes for economic production of this vegetable.

3.2.2.1 Pearson's correlation among the quantitative morphological traits

In this study, significant and positive correlation was observed between fresh leaves biomass and leaf width, leaf length, flower diameter and days to 50% flowering. These traits proved to be superior in contributing to biomass yield and they can be used for improvement of foliage in low yielding accessions. However, there was a significant and negative correlation between fresh leaves biomass and number of leaves per plant as well as the number of branches per plant. The results agree with findings of [17] who reported a negative significant correlation between average number of leaves per plant and the total plant weight nevertheless, there was a significant positive correlation between number of leaves per plant and the total weight of the plant. Adebo et al [11] reported a positive correlation between the fresh leaf biomass and number of leaves and branches.

There was a significant and positive correlation between the number of pods per plant and number of leaves per plant, and leaf length width ratio. This may possibly suggest that the more the surface area of the leaf and number of leaves, the plant can produce enough assimilates to partition for the reproductive cycle particularly in producing the pods for seeds production. In a study by [27], it was reported that a significant positive correlation was recorded for fresh leaves weight with days to 50% flowering. A strong positive correlation was observed between days to 50% flowering and plant height, number of seeds per pod and pod diameter, number of branches and fresh and dry mass in the current study and these results are in contrast with those of [19] who reported a strong negative correlation between number of days to 50% flowering and leaf length width ratio, number of pods per plant.

3.2.2.2 Principal component analysis for the qualitative and quantitative morphological traits

In this study, the principal component generated 34 PCs and apportioned the total variance for

only the first four principal components. These four components contributed 58.72% to the total variability of the morphological traits with an eigenvalue greater than 2, suggesting that, these accessions varied greatly in most of the studied characters. In agreement with these findings, [27] reported that in the PCA the first five PCs having eigenvalue greater than 1 explained 75.93% of the total variation of *Corchorus spp*. Interestingly, [24] found that the first principal component (PC) explained 49%, the second 23% and the third 12% of the total of 85% morphological variation, . The main qualitative trait which accounted for most variability in PC1 compared to the rest of the traits was leaf apex (leaf shape). [16] suggested that foliar characters are more important in characterizing *Corchorus spp.*
In the current study, the number of leaves, branches per plant contributed more positively for variations observed in PC2 and PC3, respectively. Similarly, [19] reported that, in PC2, the phenotypic attributes that mainly contributed to the variability among the accessions were leaf width, number of branches and number of seeds per pod while the number of leaves per plant were the more contributing factor in the PC3. In the current study**,** the PC3, was more associated with the pods/ seeds (pod length and weight of 1000 seeds) and some of the vegetative components including plant height and primary and secondary branches. Interestingly, [17] reported that, PC3 describes 11.53% of the variation and is defined on the positive side for leaf length, petiole length, 1000 seed weight, fruit length and then on the negative side for stem diameter.

3.2.2.3 Cluster analysis of qualitative and quantitative morphological traits

Using all morphological traits to show the current genetic divergence across all the studied Jew's mallow accessions, the cluster analysis grouped the 49 accessions into four clusters, as shown in the Dendrogram (Fig. 1). This closely compares to [12, 22], who generated a dendrogram that grouped the studied accessions into 5 clusters and [11, 29] generated six clusters.

Generally, the results revealed the presence of genetic diversity in the set of Jew's mallow genotypes and the efficiency of the morphological traits chosen to distinguish the genotypes. Contrary, [19, 20, 17] reported that, cluster analysis grouped the accessions based on their origin into clusters and showed high diversity for most of the traits, demonstrating the homogeneity of accessions from specific location. The current results revealed that clustering of the accessions was based on shared similarities on the quantitative and qualitative morphological characteristics rather than on their geographical origin. Similarly [24, 22, 11], the dendrogram obtained based on morphological traits revealed the genetic diversity in the set of Jew's mallow genotypes. Contrary, (19, 12] reported that, cluster analysis grouped the accessions based on their geographical origin.

4. CONCLUSION

It can be concluded that, there exists variability amongst the accessions and is attributed to the qualitative and quantitative traits studied. Because of superiority for some of the quantitative traits, some accessions could serve as potential parents for improvement of Jew's mallow in Botswana. Significant correlation between the leaf yield and related attributes indicated the potential accessions to use for foliage yield improvement. Based on biomass yield, accessions such as Bafia, Aziga, ExCameroon, Local big leaves, TOT6684, MLJM4, MLJM5, SUD2, SUD3 had the highest leaf fresh biomass and could be used as potential parental lines for improvement of leaf yield. Accessions such as Delele2, Delele3, Panda and Panda1 can be selected for early maturity, a mechanism that most of plants use to escape the abiotic stress amongst all the studied accessions. These accessions can also be selected for high number of pods and leaves. Accessions such as IP1, IP2, UGJM13, SUD1 and TOT4670 can be selected for plant height and number of branches. The characters such as number of leaves, number of branches, plant height have been reported as traits proved to be superior in contributing to biomass yield.

Accessions such as MIX, SUD4, TOT6278 and TOT4713 could be selected as parental lines for seed yield improvement through number of seeds per pod, number of pods per plant and 1000seeds weight as has been observed in the current study. In considering both seed yield and leaf yield as important agronomic traits for the selection of promising accessions, the challenge is to balance the leaf yield and seed yield as these were inversely related in the current study. Accessions with high leaf yield had relatively low seed yield, however, the leaf yield as harvestable part remains more important than the seed in the current study. Therefore, the accessions with high leaf yield are recommended for acceptability of Jew's mallow as a vegetable in Botswana.

5. RECOMMENDATIONS

Further studies may be done in different agro-ecological zones to see the stability of different accessions.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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