Journal of Aridland Agriculture 2024, 10: 127-141
doi: 10.25081/jaa.2024.v10.8968
https://updatepublishing.com/journal/index.php/jaa

Research Article

ISSN: 2455-9377

Evaluation of the diversity of the morpho-agronomic characteristics of *Corchorus olitorius* L. cultivars developed in Saudi Arabia

Widad S. ALJuhani[1]*, Ashwaq Yousef ALJohani[2]

[1]Department of Biology, Faculty of Science, Umm Al-Qura University, 24381 Makkah, Saudi Arabia, [2]Research Laboratories Centre, Faculty of Science, Umm Al-Qura University, 24381 Makkah, Saudi Arabia

ABSTRACT

Corchorus olitorius is considered a crop with high nutritional value. The *C. olitorius* crop is cultivated in many regions of Saudi Arabia. There is a lack of research on genetic diversity among these varieties. This work aimed to evaluate the diversity in the morphological characteristics of KSA jute germplasms and compare them to international germplasms. This study included 8 local jute germplasm seeds collected in Saudi Arabia and 16 international jute germplasm seeds from Asia, Africa and the USA. Twenty-one quantitative and qualitative characteristics of the jute samples from the stem, leaves, and fruits were evaluated. These characteristics were evaluated using many reliable statistical methods, such as multivariate analysis and one-way analysis of variance (ANOVA). Morphological traits, especially plant height, days to 50% flowering, leaf blade length, leaf blade width, leaf petiole length, pod pedicel length, pod length, pod width, number of pods per plant and leaf area, significantly differed among the jute samples. This is the first study to compare local jute germplasms in the KSA to international, to provide important information on their morphological diversity. This information can be used in crop improvement and conservation programs.

Received: May 28, 2024
Revised: October 06, 2024
Accepted: October 10, 2024
Published: November 09, 2024

***Corresponding author:**
Widad S. ALJuhani
E-mail: wsjuhani@uqu.edu.sa

KEYWORDS: Assessment, Characteristics, Diversity, Germplasm, Morpho-agronomic, Jute, Variation

INTRODUCTION

Corchorus or 'jute' is a genus in the Malvaceae Juss family. It has high economic importance as a source of fibres. In addition, *Corchorus olitorius* is considered a crop with high nutritional value (Zhang *et al.*, 2019) and contains flavonoids, phenols, amino acids, and several essential minerals (Adebo *et al.*, 2015). The 'jute' crop has been successfully grown in subtropical regions in Africa, America, Australia, and Asia (Benor, 2018). The jute crop faces many difficult conditions, such as a lack of water and soil salinity, similar to other crops grown in arid lands.

Previous studies have investigated many morphological characteristics of leaves, fruits, and seeds. Most of these studies confirmed high morphological differences among cultivars. Adebo *et al.* (2015) assessed genetic diversity in addition to variations in quantitative and qualitative characteristics and mentioned the importance of morphological traits. Furthermore, (Nyadanu *et al.*, 2016) assessed jute samples from Ghana and reported significant variation among cultivars in terms of phenomic features. Dube *et al.* (2019) estimated the quantitative characteristics of 11 Corchorus accessions from South African and world vegetable centres, and the study confirmed clear variations among the samples based on the assessed characteristics.

The characteristics of the leaves and stems are highly diverse among cultivars, and Miah *et al.* (2020) noted great variability between *C. olitorius* cultivars during screening of their morphometric characteristics. Mia *et al.* (2020) studied 12 *C. olitorius* in regions of Bangladesh and noted variations in morphological and anatomical features and mentioned correlations between morphological and anatomical traits and genotypes.

Mujahid (1989) reported that *C. olitorius*, *C. tridens*, and *C. depressus* species grow naturally in Saudi Arabia. The cultivation of *C. olitorius* species is common in several regions of Saudi Arabia. The cultivar is called by the name of the region. These germplasms of jute cultivars are preserved in the seed repository of the Ministry of Agriculture and Water.

However, there is a lack of research on genetic diversity among these varieties. This work aimed to evaluate the morphological diversity of "'jute" accessions (*Corchorus olitorius* L.) in Saudi Arabia. Comparison of the morphological characteristics of the jute cultivars in the KSA with those from the international seed repository.

MATERIALS AND METHODS

Sample Collection

The genetic material or samples (seeds) of 7 cultivars of Jute "Molokhia" (*Corchorus olitorius* L.) were collected from the seed repository of the Ministry of Environment, Water and Agriculture of Saudi Arabia, and the seeds of 6 cultivars were collected from commercial stores in Saudi Arabia. In addition to 11 international cultivars from Asia (Japan, India, China), Africa (Tunisia, Libya, Egypt) and the USA, these seeds were collected from the IPK Gatersleben repository (Germany). The names, codes, countries, and sources of the seed samples are listed in Table 1.

Seed Planting

Seed sample planting was performed in pots of plastic (PVC) with three pots per cultivar (replications) and 4 seeds per pot. The plants were 26.5 cm in diameter and 24.5 cm in height, and from October to February 2021-2022, sterilized soil, a mixture of sandy agricultural soil, and pitmos (purchased from commercial stores in Macca, Saudi Arabia, produced by Al-Bustan Nurseries Company) were used. The plants were irrigated twice per day under temperature conditions ranging from 18 °C to 30 °C.

Jute seeds were provided with nutrients, including nitrogen, phosphorus, and potassium, to help them grow, flower, and bear fruit, and fertilizer was applied four weeks after planting. Soil fertilizer NPK (concentration 12-48-12), potassium humate once a week to support vegetative growth, and high potassium paper compost (35-12-12) were used at varying intervals to support flowering and the emergence of fruits 10 weeks after planting. The morphological measurements of plant height and leaf height were taken when the plant was 108 days old, and flower and fruit measurements were also calculated on Day 108 (Figures 1 & 2).

Morphological Traits Measurement and Evaluation

Twenty-one quantitative and qualitative traits were evaluated for the stem, leaves, and fruits (Table 2), and the traits were investigated in five replicates for each of the 24 accessions of *C. olitorius*. The quantitative traits were plant height, days to 50% flowering, leaf petiole, leaf blade length, leaf blade width, pod pedicel length, pod length, pod width, number of pods per plant, area of leaf, and area of pods. These parameters were assessed as described in (Loumerem & Alercia, 2016) using measuring tape and ImageJ software version 1.54c (Schneider *et al.*, 2012). The qualitative traits (branching from higher nodes, stem colour, presence of stem hair, leaf colour, leaf shape, leaf base, apex shape, leaf margin, pod shape and petal colour) were estimated (Table 2). Colour was determined by the colour bar as described by (Loumerem & Alercia, 2016) with modifications. Supplementary Tables S1 and S2 provides details for evaluating methods for each quantitative and qualitative characteristic.

Table 1: List of seed samples utilized in the current study

S. No.	Samples Codes	Country	Source
1	India	India	IPK Gatersleben, Germany
2	China	China	
3	Libya1	Libyan Arab Jamahiriya	
4	Libya2	Libyan Arab Jamahiriya	
5	Libya3	Libyan Arab Jamahiriya	
6	Libya4	Libyan Arab Jamahiriya	
7	Tunisia1	Tunisia	
8	Tunisia2	Tunisia	
9	Tunisia3	Tunisia	
10	Egypt1	Egypt	
11	Japan	Japan	
12	SA-Lay	Saudi Arabia (allayth)	Saudi Arabia commercial store, Sendian Alarabi for Agriculture
13	Egypt2	Egypt - Giza (Saidy)	
14	Egypt3	Egypt (Saidy)	
15	USA	Origin: U.S.A -(Saidy)	
16	Egypt4	Egypt (Saidy)	
17	Egypt5	Egypt	
18	S.A (Giz)	Saudi Arabia (Gizan)	Ministry of Environment, Water and Agriculture, Riyadh
19	S.A (Raf)	Saudi Arabia (Rafha)	
20	S.A (Mad)	Saudi Arabia (Madina)	
21	S.A (Tai)	Saudi Arabia (Taif)	
22	S.A (Qat)	Saudi Arabia (Al-Qateef)	
23	S.A-M-(Muz)	Saudi Arabia [Mecca (Al-Muzaiq)]	
24	SA-M-Yam	Saudi Arabia [Mecca (Al-Yamania)]	

Table 2: Morpho-agronomic characteristics assessed in this study

S. No.	Quantitative Character	Code	Unit	Qualitative Character	Code
1.	Plant height	PH	cm	Leaf color	LC
2.	Days to 50% flowering	DF	day	Leaf shape	LS
3.	Leaf petiole length	LP	cm	Leaf base shape	LBS
4.	Leaf blade length	LB	cm	Leaf apex shape	LAS
5.	Leaf blade width	LBW	cm	Leaf margin	LM
6.	Pod pedicel length	PPL	cm	Branching from higher nodes	BHN
7.	Pod length	PL	cm	Stem color	SC
8.	Pod width	PW	mm	Stem hair	SH
9.	Number of pods per plant	NP		Pod shape	PS
10.	Area of leaf	AL		Petal color	PC
11.	Area of pods	AP			

Data Analysis

To identify the leaf and fruit traits that had discrimination power, a morphometric dataset was utilized to implement

Figure 1: The eleventh week of cultivation showing flower growth in some jute samples

multivariate analysis PCA. It was performed in XLSTAT v. 2023.1.1. to show the relationships between the cultivars of each country, as well as between individuals of different countries (XLSTAT, 2023). PCA was used to group samples within groups based on the similarity of the morphological characteristics that were estimated.

The box plot and one-way ANOVA and R-squared values were calculated in the program GraphPad Prism Version 9.5.1 based on 999 permutations to analyse the differences between samples from eight geographical regions (GraphPad, 2023). Evaluating the variation between samples depends on variables (Sneath & Sokal, 1973). The R-squared values ranged from 0.1 to 1, where values ≥0.9 were considered the highest.

To screen the relationships between jute cultivars based on similarity, a cluster dendrogram was constructed in R-Studio software V.2.0 (RStudio, 2020) using the 'factoextra' package.

Figure 2: The twelfth week of cultivation showing fruit growth in some jute samples. The arrows points to the fruits.

RESULTS

Variation in Flowering and Fruiting Time

In general, the seed samples were growing well, and we noticed that the genotypes were sensitive to short day lengths, which caused them to bloom prematurely. After 69 days or the 11th week, the international specimens (Libyan2, Libyan3, Libyan4, Tunisia1, Tunisia2, Tunisia3, Egypt1, and Japan) entered the flowering stage, as shown in Figure 1.

However, after flowering occurred in local and international samples (India, S.A. (Raf), S.A. (Tai), and S.A. (Mad)) 76 days (the 12th week), in addition to samples (S.A. (Lay), Egypt2, Egypt3, U.S.A., Egypt4, Egypt5, S.A.Giz), S.A.-M. (Muz), S.A.-M. Yam, S.A. (Qat), China and Libyan1). Flower development continued for 83 days (the 13th week). We did not observe any differences in the colour of the flowers between the samples.

The pods started to appear after 61 days or 12 weeks, as shown in Figure 2, for the Libyan2, Libyan3, Libyan4, Tunisia1, Tunisia2, Tunisia3, Egypt1 and Japan samples. The fruits of the samples (India, S.A. (Raf), S.A. (Taf), and S.A. (Mad)) appeared after 83 days (the 13th week). In some local samples (S.A. (Lay), S.A. (Giz), S.A.-M. (Muz), S.A.-M. (Yam), and S.A. (Qat)) and international samples (Egypt2, Egypt3, Egypt4, Egypt5, China and Libyan1), fruits appeared after 90 days (the 14th week).

Assessment of variation in descriptive characteristics

The Supplementary Table S3 shows the descriptive traits of the leaf samples. There was some variation in the descriptive traits of the cultivars that were examined. The leaf apex shape trait ranged from very acute in each cultivar (India, China, Libya1, S.A-M-Yam, S.A. (Qat), and S.A. (Mad)) to acute in the remaining samples.

The stem colour ranged from dark green to light green or from brown to dark red for each of the following cultivars: light green was detected in samples from the Indian, Libyan2, Libyan4, Tunisia1, Tunisia2, Egypt3, Egypt4, S.A. (Giz), S.A-M-Yam, S.A. (Mad), and S.A-Tia cultivars. A dark green colour was observed for the China, S.A. (Raf) and S.A. (Qat) cultivars. A brown stem colour was found in the Libyan1, Tunisia3, S.A-Lay, Egypt2, U.S.A, Egypt5 and S.A-M-(Muz) samples. In some samples, the stem colour was dark red, as in the case of the (Libyan3, Egypt1, Japan) cultivar.

There was variation between the samples in terms of leaf colour. The dark green colour ranged among the cultivars (India, Libyan1, Libyan2, Tunisia1, S.A. (Lay), Egypt3, U.S.A., S.A. (Giz), S.A.-M.Yam, S.A.-M. (Muz), S.A. (Mad), and S.A. (Tai)). The cultivars (China, Libyan3, Libyan4, Tunisia2, Tunisia3, Egypt4, Japan, Egypt1, Egypt5) had light green leaves. The leaves of the Egypt2 and S.A. (Raf) cultivars tended to be dark green, and the leaves of the S.A. (Qat) cultivar tended to be glossy light green (Figure 3).

The pod shapes were subcylindrical and curved in samples from India, Libyan2, Libyan4, Tunisia1, Japan, Egypt4, S.A. (Mad), S.A-M-Yam), S.A-M-(Muz), S.A. (Qat), S.A. (Giz) and S.A. (Raf). However, subcylindrical and straight shapes were observed in pod cultivars (China, Libyan1, Libyan3, Tunisia2, Tunisia3, S.A. (Lay), Egypt1, Egypt2, U.S.A., Egypt3, Egypt5, S.A. (Tai)) (Figure 4).

Assessment of Quantitative Characteristics

Three axes, namely, Axes 1, 2 and 3 (49.134, 15.164 and 11.476, respectively), had high eigenvalues according to principal component analysis (Table 3 & Figure 5).

The characteristics that represent high loading (+/-) in the first three axes of the PCA are shown in Table 4. The area of leaf (AL) and number of pods per plant (NP) represent the highest (+ & -) loadings on Axis 1 (0.925 & -0.105). The number of pods per plant (NP) and the pod pedicel length (PPL) had the highest loading values on Axis 2 (0.762 and -0.493, respectively). Concerning Axis 3, pod width (PW) had the highest positive loading (0.748), whereas pod length (PL) had the highest negative loading on Axis 3 (-0.256).

Overall, the characteristics important for distinguishing between jute cultivars in the current study were plant height,

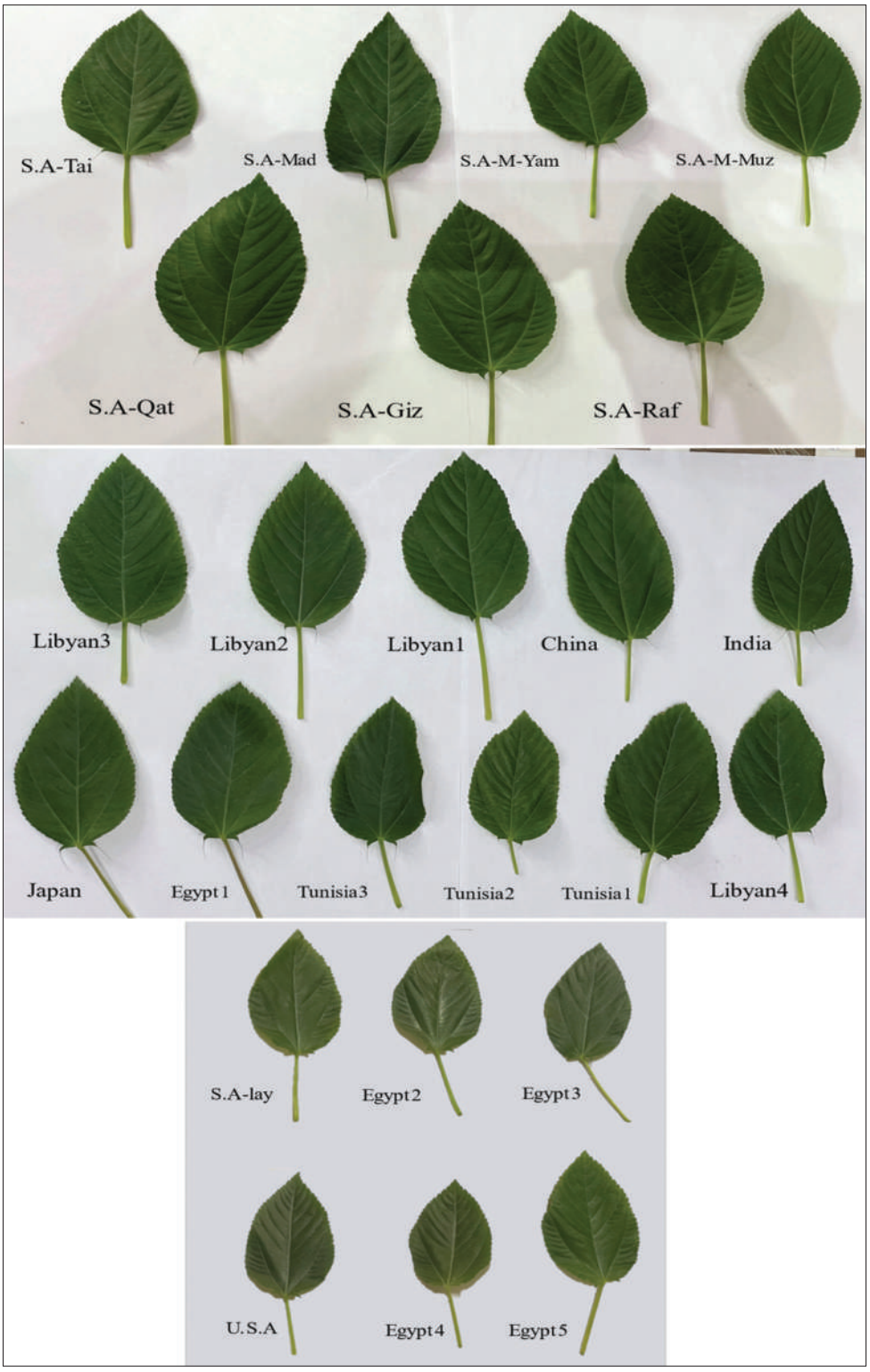

Figure 3: Comparison of leaf morphological characteristics in this study

Table 3: Eigenvalues of PCA calculated based on morphological characteristics

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
Eigenvalue	5.405	1.668	1.262	0.885	0.604	0.373	0.328	0.231	0.133	0.102	0.008
Variability (%)	49.134*	15.164*	11.476*	8.048	5.495	3.392	2.985	2.096	1.209	0.930	0.071
Cumulative %	49.134	64.298	75.774	83.822	89.317	92.709	95.694	97.790	98.999	99.929	100.000

*Indicate the largest values

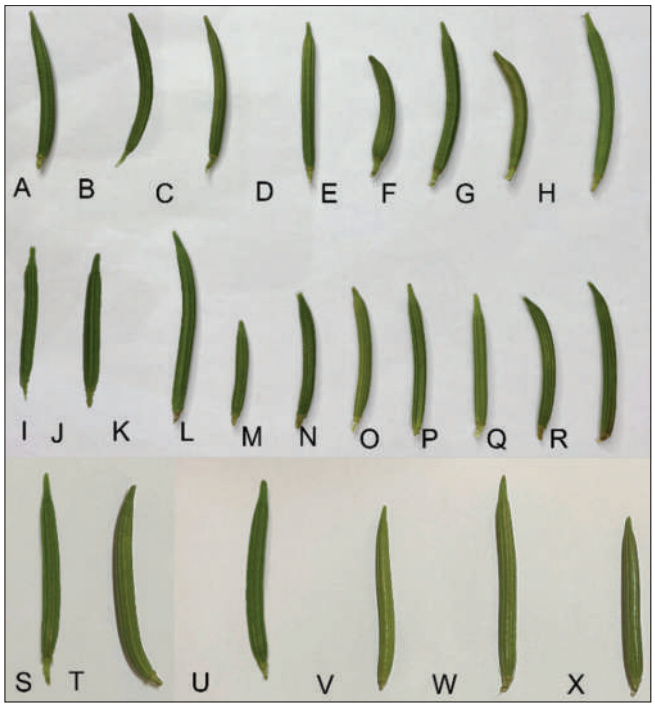

Figure 4: Comparison of fruit shapes in international and local jute samples. A: SA-Giz, B: SA-M-Yam, C: SA-M-Muz, D: SA-Tia, E: SA-Qat, F: SA-Raf, G: SA-Mad, H: India, I: Chaina, J: Libyan1, K: Libyan2, L: Libyan3, M: Libyan4, N: Tunisia1, O: Tunisia2, P: Tunisia3, Q: Egypt1, R: Jaban, S: Egypt5, T: Egypt4, U: USA, V: Egypt3, W: Egypt2, X: SA-Lay.

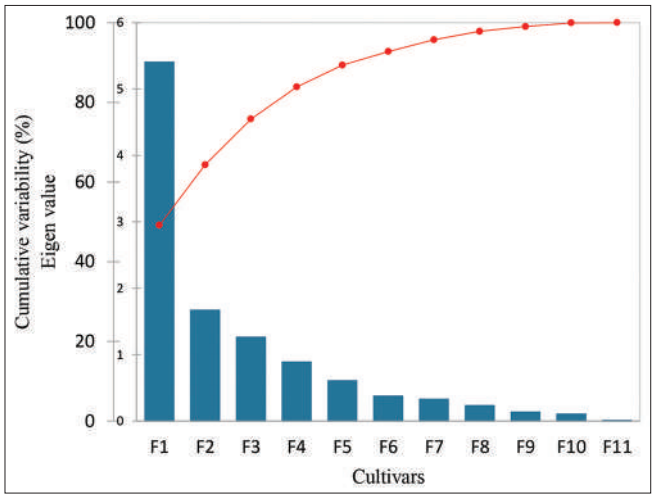

Figure 5: Principal component analysis eigenvalues for local *Corchorus olitorius* from the KSA and international samples based on observations of 11 leaf and fruit traits

days to 50% flowering, leaf petiole length, leaf blade length, leaf blade width, pod pedicel length, pod length, pod width, number of pods per plant and area of leaf, as shown in Figure 6. The PCA results showed that cultivars from the same country tended to be closely related. All samples from Saudi Arabia (S.A. (Giz), S.A. (Raf), S.A.-M. (Muz), S.A.-M.Yam, S.A. (Qat), S.A. (Mad), and S.A. (Tai)) were located close to Axis 1 according

Table 4: Loadings on PCA axes based on morphological traits

Characteristic Code	F1	F2	F3	F4	F5
PH	0.736	0.356	-0.089	-0.345	0.298
DF	0.809	-0.275	0.036	-0.272	0.262
LPL	0.871	-0.105	-0.072	0.098	0.236
LBL	0.737	-0.200	-0.201	0.430	-0.192
LBW	0.890	-0.206	0.044	0.199	0.014
PPL	0.212	-0.493*	0.654	-0.416	-0.095
PL	0.716	0.394	-0.256*	-0.303	-0.290
PW	0.434	0.220	0.748*	0.203	-0.220
NP	-0.105*	0.762*	0.386	0.250	0.335
AL	0.925*	-0.214	0.010	0.261	0.074
AP	0.708	0.547	-0.057	-0.145	-0.309

*Indicates the largest negative and positive values

Table 5: ANOVA results of 11 morphological characteristics. The P-value is defined as the probability of no differences between the samples from 1000 randomized samples.

Characteristics	P-value	R squared
Plant height (cm)	<0.0001	0.70
Leaf petiole length (cm)	<0.0001	0.80
Leaf blade length (cm)	<0.0001	0.48
Leaf blade width (cm)	<0.0001	0.64
Pod pedicel length	0.0979	0.26
Pod length (cm)	<0.0001	0.61
Pod width	0.0096	0.33
Number of pods per plant	0.0779	0.14
Area of leaf	<0.0001	0.34
Area of pods	<0.0001	0.61
Days to 50% flowering "DAY"	<0.0001	0.97

P-value=probability of no differences between the samples from 1000 randomized samples

to PCA, as shown in Figure 6, and all samples from the same cultivar, Saidy of Egypt and the USA, were also located very close to Axes 2. The samples from Tunis and Libya were located towards negative Axis 2.

Table 5 shows the ANOVA results. The traits with the greatest variation between samples were days to 50% flowering, leaf petiole length, and plant height (P value <0.0001 and R squared= 0.97 & 0.80, & 0. 70). Cultivars from Saudi Arabia (S.A., Giz; S.A., Qat; SA-M., Muz; and S.A., M-Yam) exhibited remarkable variation from the rest of the samples in the Days to the 50% flowering "Day" trait, with a mean of 89.8 and 84.8, a maximum of 93.0 and 88.0, a minimum of 86.0 and 81.0, and a standard deviation (SD) of 2.3 (Supplementary Table S4). The cultivar "S.A (Qat)" from Saudi Arabia presented the greatest variation in leaf petiole length, with a mean of 7.7, maximum of 9.2, minimum of 6.0, and standard deviation (SD) of 1.1 (Supplementary Table S4). The Egypt5 and USA cultivars exhibited the greatest variation in the plant height trait, with mean values of 128.9 and 124.8, maximum values of 150 and 155, minimum values of 73.5 and 74, and standard deviations (SDs) of 24.1 and 28, respectively. This variation is also clear in the results of Tukey's HSD test in Figure 7.

The relationships between jute cultivars are shown in a cluster dendrogram based on morphological characteristics

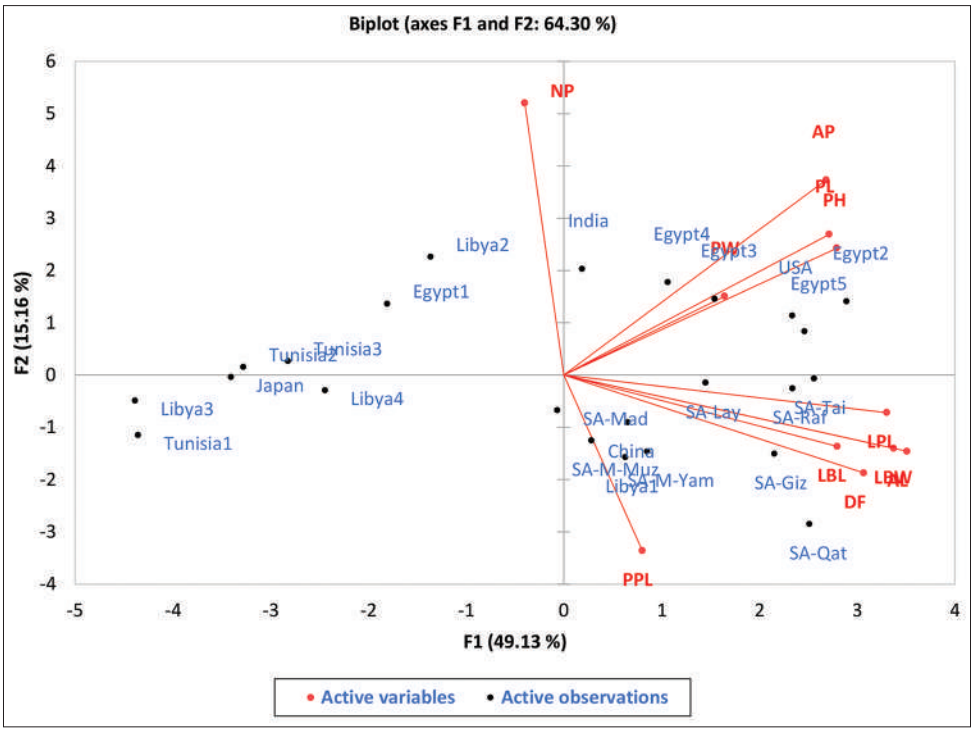

Figure 6: Loading plots and cluster loadings for morphological characteristics and *Corchorus olitorius* samples from the SA and international samples on PCA Axes 1 and 2

(Figure 8). The accessions were located within three clusters and approximately six subclusters. The first main cluster, "red", which contained accessions divided within two subbranches. The first subbranch consisted of a mixture of Japan, Libya (Libya3 and Libya4), and Tunisia (Tunisia1 and Tunisia2), and the second subcluster included samples from Egypt1, Libyan (Libyan2) and Tunisia3.

The second cluster, "green", included two subclusters, most of which were local jute cultivars of Saudi Arabia. The first subbranch included samples from Saudi Arabia (SA-Giz, SA-M-Muz, SA-Mad, SA-Tai, SA-Lay, SA-M-Yam), Libya (Libya1) and Egypt (Egypt5), while subbranch two consisted of cultivars from Saudi Arabia (SA-Raf and SA-Qat), China. The samples in the third main cluster, "blue", were classified into two subbranches. The first subbranch included mixed samples from Egypt (Egypt2 and Egypt3) and the USA, while the second subcluster included samples from Egypt (Egypt4) and India.

DISCUSSION

In the present work, we evaluated the morphological variations of "'jute" accessions (*Corchorus olitorius* L.) in Saudi Arabia and compared them to those of international 'jute cultivars of jute.

According to the PCA and ANOVA results (P value <0.0001), plant height, days to 50% flowering, leaf petiole length, plant height, leaf blade length, leaf blade width, pod pedicel length, pod length, pod width, number of pods per plant and area of leaf were important for distinguishing between jute cultivars in the present study. This study largely supports the results of a previous study (Adebo *et al.*, 2015) that assessed diversity in 40 cultivars of *Corchorus* spp. from Benin and indicated a large variation in the morphological characteristics of leaves and fruits. Additionally, (Nyadanu *et al.*, 2016), in an ethnobotanical study of 50 jute samples from Ghana, confirmed significant diversity between cultivars when 18 morphological characteristics were screened.

Furthermore, this work is in agreement with the findings of Kwarteng *et al.* (2018), who evaluated 20 characteristics of 106 jute accessions (*C. olitorius*) in Ghana. They noted that traits such as the length of the leaf blade, the width of the leaf blade, the colour of the fruit at maturity, the height of the plant, and the length of the fruit were the most important in discriminating between accessions. Additionally, Miah *et al.* (2020) noted great variability between *C. olitorius* cultivars during the screening 22 characters of stems and leaves. The results showed that the morphometric traits of the accessions differed.

In general, morphological characteristics currently represent significant importance in the description and identification of different phenotypes of cultivars. Significant differences in morpho-agronomic traits among bottle gourd accessions have recently been reported (Flores-Chacón *et al.*, 2024), and these differences help in grouping accessions into three clusters according to similarity. Moreover, there is sufficient diversity in morpho-agronomic traits among the genotypes

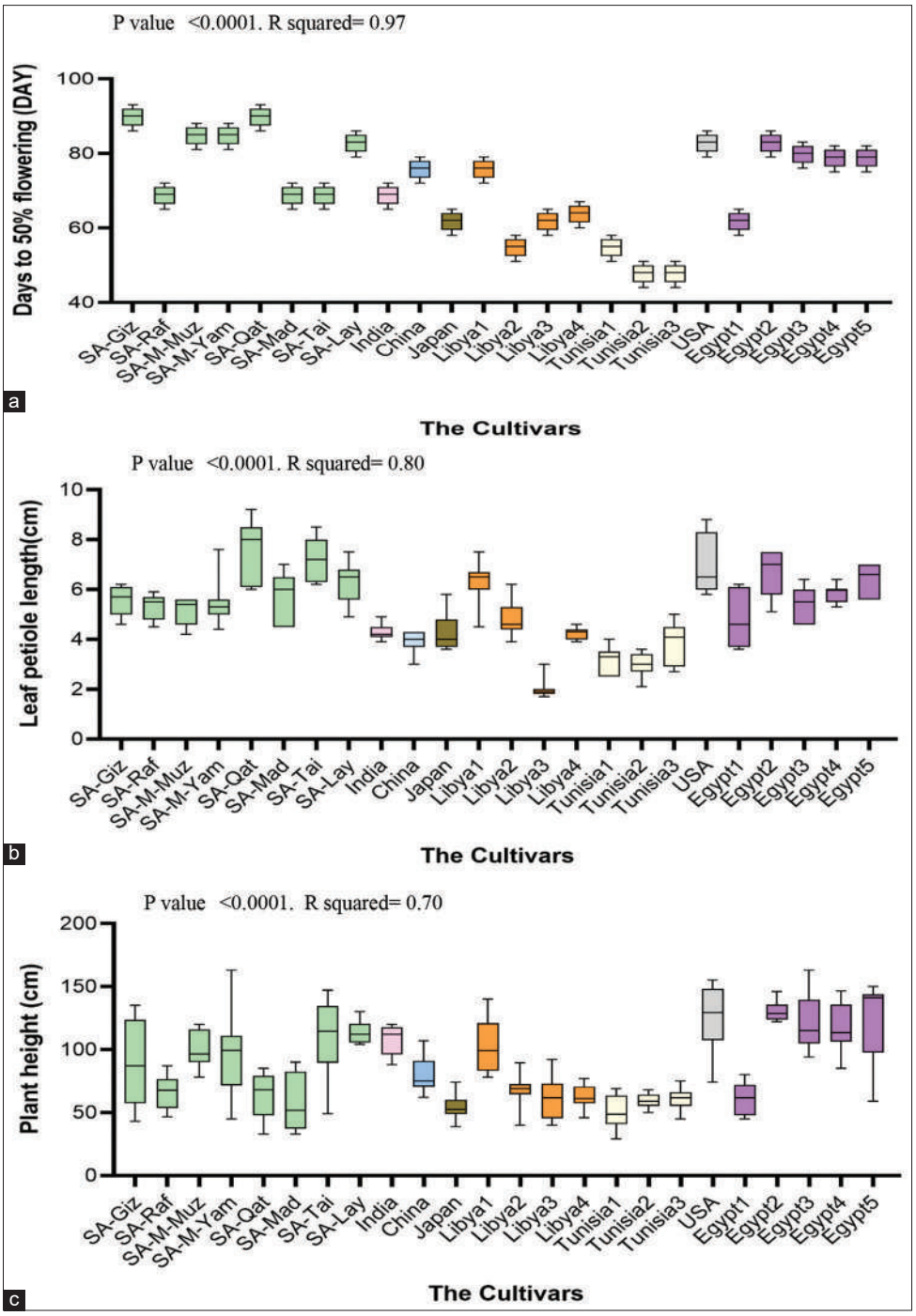

Figure 7: Morphological characteristics with the greatest variation in HAD among the *Corchorus olitorius* cultivar samples. a) Days to 50% flowering, b) Leaf petiole length and c) Plant height

of Ethiopian black cumin genotypes (Gebremedin *et al.*, 2024). Morphological variability is important for characterizing and evaluating Capsicum Chinese genotypes (Alves *et al.*, 2024)

The number of jute varieties in the Kingdom of Saudi Arabia is limited, and there is not enough information about their genetic diversity, in addition to the vital pressures associated with the cultivation of this crop, which pose great challenges, such as salinity, water shortages, and soil poverty. In fact, conserving these varieties requires a greater understanding of the genetic and morphological diversity of the germplasms and a good description of the distinctive features of each variety to exploit them in programs to improve quality and hybridization. This study provides valuable and unique information, an evaluation of the morphological diversity of local jute cultivars in the KSA and a comparison of local and international germplasm of jute for the first time.

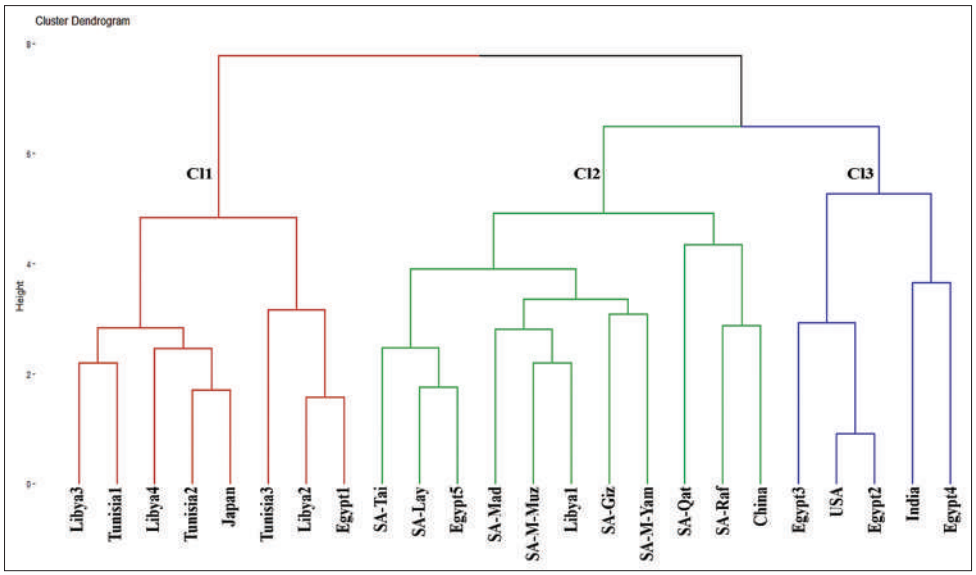

Figure 8: Cluster dendrogram of local Saudi and international accessions of *Corchorus olitorius* based on 11 morphological characteristics of leaves and fruits. Bootstrap values were computed over 1000 replications

CONCLUSION

In this study, we analysed the morphological characteristics of *C. olitorius* detect the best traits reflect high level of diversity in Saudi Arabia entries. This study encourages the examination morphological characteristics, especially vegetative ones, and the use it as reliable tools for identifying cultivars, preservation in banks, improving cultivars quality, and hybridization programs in jute. Results of this study will be useful for optimizing reproduction and extending the genetic base of breeding. Outcomes of this study can be used for achieving goals related to increased yield, *C. olitorius* production, plant adaptability, and disease resistance. The results of this study will be useful for those interested in the production of *C. olitorius*, in terms of selecting cultivars that show a high degree of genetic variation, as cultivars with low genetic diversity are vulnerable to biotic and abiotic stresses.

REFERENCES

Adebo, H. O., Ahoton, L. E., Quenum, F., & Ezin, V. (2015). Agro-morphological Characterization of *Corchorus olitorius* Cultivars of Benin. *Annual Research & Review in Biology, 7*(4), 229-240. https://doi:10.9734/arrb/2015/17642

Adeyemo, O. A., Ayodele, O. O., Ajisafe, M. O., Okinedo, U. E., Adeoye, D. O., Afanou, A. B., Akinsemoyin, F. A., Ogunjobi, O. O. Kasali, O. J., & Chukwudiri, E. E. (2021). Evaluation of dark jute SSR markers and morphological traits in genetic diversity assessment of jute mallow (*Corchorus olitorius* L.) cultivars. *South African Journal of Botany, 137*, 290-297. https://doi.org/10.1016/j.sajb.2020.10.027

Alves, S. R. M., Lopes, R., Meneses, C., Valente, M. S. F., Martins, C. C., Ramos, S. F., Oliveira, I., de Jesus Pinto Fraxe, T., Costa, L., & Lopes, M. T. G. (2022). Morpho-Agronomic Characterization, Sample Size, and Plot Size for the Evaluation of *Capsicum chinense* Genotypes. *Horticulturae, 8*(9), 785. https://doi.org/10.3390/horticulturae8090785

Bashandy, T., & El-Shaieny, A.-H. A. H. (2021). Morphological and Molecular Marker Screening for Drought Tolerance in Egyptian Jew's Mallow (*Corchorus olitorius* L.) Landraces. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 69*(1), 79-89. https://doi.org/10.11118/actaun.2021.009

Benor, S. (2018). Molecular phylogeny of the genus *Corchorus* (Grewioideae, Malvaceae s.l.) based on nuclear rDNA ITS sequences. *The Crop Journal, 6*(5), 552-563. https://doi.org/10.1016/j.cj.2018.03.007

Dube, S. P., Marais, D., Mavengahama, S., Van Jaarsveld, C. M., & Gerrano, A. S. (2019). Characterisation of agro-morphological traits of *Corchorus* accessions. *Acta Agriculturae Scandinavica, Section B - Soil & Plant Science, 69*(2), 126-134. https://doi.org/10.1080/09064710.2018.1514419

Flores-Chacón, S., Carreño, G., Maldonado, C., & Contreras-Soto, R. (2024). Comprehensive Assessment of Morphological Diversity in Bottle Gourd (*Lagenaria siceraria*) Accessions: A Focus on Roots and Morpho-Agronomic Traits. *Diversity, 16*(3), 136. https://doi.org/10.3390/d16030136

Gao, J., Guo, G., Guo, Y., Wang, X., & Du, Y. (2011). Measuring plant leaf area by scanner and ImageJ software. *China Vegetables, 1*(2), 73-77.

Gebremedin, B. D., Asfaw, B. T., Mengesha, W. A., & Abebe, K. A. (2024). Genetic diversity of Ethiopian black cumin (*Nigella sativa* L.) based on morpho-agronomic characteristics. *Euphytica,* 220, 51. https://doi.org/10.1007/s10681-024-03315-4

Ghosh, A., Biswas, B. K., & Arifuzzaman, M. (2020). Variability and Character Association Study in Morphological Traits of Tossa Jute (*Corchorus olitorius* L.). *The Agriculturists, 18*(1), 116-128. https://doi.org/10.3329/agric.v18i1.49464

GraphPad. (2023). GraphPad Prism version 10.0.0 for Windows. Boston, Massachusetts, USA: GraphPad Software. Retrieved from https://www.graphpad.com

Helaly, A., Alkharpotly, A., Mady, E., & Craker, L. E. (2017). Characterization of Four Molokhia (*Corchorus olitorius*) Landraces by Morphology and Chemistry. *Journal of Medicinally Active Plants, 5*(1-4), 1-6. https://doi.org/10.7275/R52F7KMD

Kwarteng, A. O., Amoah, R. A., Nyadanu, D., Nyam, C. K., Ziyaaba, J. Z., Abogoom, J., Aziz, A., Anokye, K. D., Dufie, M., Boakye, M. O., & Danso, E. O. (2018). Core collection of two important indigenous vegetables; Gboma eggplant (*Solanum macrocarpon* L.) and Jute mallow (*Corchorus olitorius* L.) in Africa: An important step for exploitation of existing germplasm and development of improved cultivars. *Australian Journal of Crop Science, 12*(09), 1398-1409. https://doi.org/10.21475/ajcs.18.12.09.PNE993

Loumerem, M., & Alercia, A. (2016). Descriptors for jute (*Corchorus olitorius* L.). *Genetic Resources and Crop Evolution, 63*(7), 1103-1111. https://doi:10.1007/s10722-016-0415-y

Mia, M. M., Akter, N., Mostofa, M. G., Ahmed, S. S. U., Nur, I. J., Al-Mamun, M., & Rashid, M. H.-O. (2020). Analyses of Genetic Variability, Character Association, Heritability and Genetic Advance of Tossa Jute (*Corchorus olitorius*) Genotypes for Morphology & Stem Anatomy. *American Journal of BioScience, 8*(4), 99-112. https://doi.

org/10.11648/j.ajbio.20200804.12
Miah, A., Saha, N. R., Hossain, A. K. M. S., Ali, M. Y., & Basunia, A. K. (2020). Genetic Variability Assessment of Tossa Jute (*Corchorus olitorius* L.) Genotypes Using Morpho-Agronomic Traits. *Acta Scientific Agriculture, 4*(7), 132-138. https://doi.org/10.31080/asag.2020.04.0865
Mujahid, A. M. (1989). *Flora of Saudi Arabia*. Riyadh, SA: King Saud University Press.
Nyadanu, D., Adu Amoah, R., Kwarteng, A. O., Akromah, R., Aboagye, L. M., Adu-Dapaah, H., Dansi, A., Lotsu, F., & Tsama, A. (2016). Domestication of jute mallow (*Corchorus olitorius* L.): ethnobotany, production constraints and phenomics of local cultivars in Ghana. *Genetic Resources and Crop Evolution, 64*, 1313-1329. https://doi.org/10.1007/s10722-016-0438-4
RStudio. (2020). RStudio: integrated development for R. Rstudio Team, PBC. Boston, MA: Posit Software. Retrieved from https://posit.co/download/rstudio-desktop
Schneider, C. A., Rasband, W. S., & Eliceiri, K. W. (2012). NIH Image to ImageJ: 25 years of image analysis. *Nature Methods, 9*(7), 671-675. https://doi.org/10.1038/nmeth.2089
Sneath, P. H., & Sokal, R. R. (1973). *Numerical taxonomy. The principles and practice of numerical classification*. US: W H Freeman & Co.
XLSTAT. (2023). XLSTAT statistical and data analysis solution. Denver, Colorado: Lumivero. Retrieved from https://www.xlstat.com/en
Zhang, L., Ibrahim, A. K., Niyitanga, S., Zhang, L., & Qi, J. (2019). Jute (*Corchorus* spp.) Breeding. In J. M. Al-Khayri, S. M. Jain & D. V. Johnson (Eds.), *Advances in Plant Breeding Strategies: Industrial and Food Crops* (Vol. 6, pp. 85-113) Berlin, Germany: Springer. https://doi.org/10.1007/978-3-030-23265-8_4

SUPPLEMENTARY TABLES

Table S1: Methods for measuring quantitative characteristics

S. No.	Quantitative Character	Code	Unit	Description	References
1.	Plant height	PH	cm	Plant height at maturity measured from the base of the plant to the tip of the main stem using a measuring (cm) after 90 days of growth	Loumerem & Alercia, 2016; Helaly *et al.*, 2017; Ghosh *et al.*, 2020; Adeyemo *et al.*, 2021; Bashandy & El-Shaieny, 2021
2.	Days to 50% flowering	DF	day	Number of days from seed germination to 50% flowering	Loumerem & Alercia, 2016; Ghosh *et al.*, 2020; Adeyemo *et al.*, 2021
3.	Leaf petiole length	LP	cm	Five leaves were collected from each of selected plants and from each replication. Was measured with a meter scale in cm. (Short, Intermediate, long)	Loumerem & Alercia, 2016; Adeyemo *et al.*, 2021
4.	Leaf blade length	LB	cm	Measured from leaf base to leaf tip and excluding the petiole (Short, Intermediate, long)	Loumerem & Alercia, 2016; Adeyemo *et al.*, 2021
5.	Leaf blade width	LBW	cm	Measured from the widest point (Narrow, Intermediate, wide)	Loumerem & Alercia, 2016; Adeyemo *et al.*, 2021
6.	Pod pedicel length	PPL	cm	Short, long	Adeyemo *et al.*, 2021
7.	Pod length	PL	cm	Measured from the base of the pod (without including the calyx) to its apex. {Short (<3 cm), medium (3-5 cm), long (>5 cm)}	Loumerem & Alercia, 2016; Adeyemo *et al.*, 2021
8.	Pod width	PW	mm	The width of the pod	Adeyemo *et al.*, 2021
9.	Number of pods per plant	NP		The sum of the number of pods from all picking for a particular plant. Counted from plants at maturity stage	Loumerem & Alercia, 2016; Bashandy & El-Shaieny, 2021
10.	Area of leaf	AL		Measuring plant leaf area by scanner and ImageJ software	Gao *et al.*, 2011; Schneider *et al.*, 2012
11.	Area of pods	AP		Measuring plant pods area by scanner and ImageJ software.	Gao *et al.*, 2011; Schneider *et al.*, 2012

Table S2: Methods for estimating qualitative characteristics

S. No.	Qualitative Character	Code	Descriptors	References
1.	Leaf color	LC	Measured by color charts. (light green, dark green, glossy light green, glossy dark green, red)	Loumerem & Alercia, 2016; Adeyemo *et al.*, 2021
2.	Leaf shape	LS	Varies between species and genera. The description of leaf shape is generalized and subjective. Leaves on a plant can vary in shape and size and between individuals. (Ovate, lanceolate, palmately lobed, oblanceolate)	Loumerem & Alercia, 2016; Adeyemo *et al.*, 2021
3.	Leaf base shape	LBS	Referring to the base of a leaf blade of which the angle formed by the meeting of the margins is less than 90°. (Rounded, Oblique, Sagittate, Truncate, Hastate)	Loumerem & Alercia, 2016; Adeyemo *et al.*, 2021
4.	Leaf apex shape	LAS	The description of leaf apex shape is generalized and subjective. Leaves on a plant can vary in shape and size and between individuals. (Very acute, acute, Intermediate, obtuse, very obtuse)	Loumerem & Alercia, 2016; Adeyemo *et al.*, 2021
5.	Leaf margin	LM	This character refers to the structure or appearance of the margins of the leaves. (Entire, serrulate, dentate, serrate, double serrate, cleft)	Loumerem & Alercia, 2016; Adeyemo *et al.*, 2021
6.	Branching from higher nodes	BHN	Non-branching Branching Mixed branching	Loumerem & Alercia, 2016
7.	Stem color	SC	Measured by color charts Green Light green Dark green Brown Light red Dark red	Benor *et al.*, 2012; Loumerem & Alercia, 2016
8.	Stem hair	SH	Absent (0) Present (1)	Loumerem & Alercia, 2016
9.	Pod shape	PS	The shape of mature pods (i.e., bearing ripe seeds) in plant. Note that the description of pod shape is at best approximate. (Sub-cylindrical, straight, or curved, mixed)	Loumerem & Alercia, 2016; Adeyemo *et al.*, 2021
10.	Petal color	PC	Observation color: Yellow Bright yellow Orange	Loumerem & Alercia, 2016

Table S3: The qualitative traits of local and international *Corchorus olitorius* cultivars included in this study

Origin	Branching from higher nodes	Stem color	Stem hair	Leaf color	Leaf shape	Leaf base shape	Leaf apex shape	Leaf margin	Pod shape	Petal color
India	Branching	light green	(0) Absent	Dark green	Lanceolate	Rounded	Very acute	serrated	Sub-cylindrical and curved	Yellow
China	Branching	Dark green	(0) Absent	Light green	Lanceolate	Rounded	Very acute	serrated	Sub-cylindrical and straight	Yellow
Libyan Arab Jamahiriya1	Branching	Brown	(0) Absent	Dark green	Lanceolate	Rounded	Acute	serrated	Sub-cylindrical and straight	Yellow
Libyan Arab Jamahiriya2	Branching	light green	(0) Absent	Dark green	Lanceolate	Rounded	Very acute	serrated	Sub-cylindrical and curved	Yellow
Libyan Arab Jamahiriya3	Branching	Dark red	(0) Absent	Light green	Lanceolate	Rounded	Acute	serrated	Sub-cylindrical and straight	Yellow
Libyan Arab Jamahiriya4	Branching	light green	(0) Absent	Light green	Lanceolate	Rounded	Acute	serrated	Sub-cylindrical and curved	Yellow
Tunisia1	Branching	light green	(0) Absent	Dark green	Lanceolate	Rounded	Acute	serrated	Sub-cylindrical and curved	Yellow
Tunisia2	Branching	light green	(0) Absent	Light green	Lanceolate	Rounded	Acute	serrated	Sub-cylindrical and straight	Yellow
Tunisia3	Branching	Brown	(0) Absent	Light green	Lanceolate	Rounded	Acute	serrated	Sub-cylindrical and straight	Yellow
Japan	Branching	Dark red	(0) Absent	Light green	Lanceolate	Rounded	Acute	serrated	Sub-cylindrical and curved	Yellow
Egypt1	Branching	Dark red	(0) Absent	Light green	Lanceolate	Rounded	Acute	serrated	Sub-cylindrical and straight	Yellow
Saudi Arabia (allayth)	Branching	Brown	(0) Absent	Dark green	Lanceolate	Rounded	Acute	serrated	Sub-cylindrical and straight	Yellow
Egypt2 - Giza (Saidy)	Branching	Brown	(0) Absent	Glossy dark green	Lanceolate	Rounded	Acute	serrated	Sub-cylindrical and straight	Yellow
Egypt3 (Saidy)	Branching	light green	(0) Absent	Dark green	Lanceolate	Rounded	Acute	serrated	Sub-cylindrical and straight	Yellow
U.S.A (Saidy)	Branching	Brown	(0) Absent	Dark green	Lanceolate	Rounded	Acute	serrated	Sub-cylindrical and straight	Yellow
Egypt4 (Saidy)	Branching	light green	(0) Absent	Light green	Lanceolate	Rounded	Acute	serrated	Sub-cylindrical and curved	Yellow
Egypt5	Branching	Brown	(0) Absent	Light green	Lanceolate	Rounded	Acute	serrated	Sub-cylindrical and straight	Yellow
Saudi Arabia (Gizan)	Branching	ligth green	(0) Absent	Dark green	Lanceolate	Rounded	Acute	serrated	Sub-cylindrical and curved	Yellow
Saudi Arabia (Rafha)	Branching	Dark green	(0) Absent	Glossy dark green	Lanceolate	Rounded	Acute	serrated	Sub-cylindrical and curved	Yellow
Saudi Arabia [Mecca (Al-Muzaiq)]	Branching	Brown	(0) Absent	Dark green	Lanceolate	Rounded	Acute	serrated	Sub-cylindrical and curved	Yellow
Saudi Arabia [Mecca (Al-Yamania)]	Branching	light green	(0) Absent	Dark green	Lanceolate	Rounded	Very acute	serrated	Sub-cylindrical and curved	Yellow
Saudi Arabia (Al-Qateef)	Branching	Dark green	(0) Absent	Glossy ligth green	Lanceolate	Rounded	Very acute	serrated	Sub-cylindrical and curved	Yellow
Saudi Arabia (Madina)	Branching	light green	(0) Absent	Dark green	Lanceolate	Rounded	Very acute	serrated	Sub-cylindrical and curved	Yellow
Saudi Arabia (Taif)	Branching	Green	(0) Absent	Dark green	Lanceolate	Rounded	Acute	serrated	Sub-cylindrical and straight	Yellow

Table S4: Quantitative characteristics of leaf and fruit trait characteristics of local *Corchorus olitorius* in the KSA

Characteristics	SA-Giz					SA-Raf					SA-M-Muz				
	ST	MEDIAN	MEAN	MIN	MAX	ST	MEDIAN	MEAN	MIN	MAX	ST	MEDIAN	MEAN	MIN	MAX
Plant height (cm)	14.3	97	99.1	78	120	12.7	67.8	66.7	46.5	87	31.2	87	88.3	43	135
Leaf petiole length(cm)	0.5	5.4	5.2	4.2	5.6	0.5	5.5	5.4	4.5	5.9	0.6	5.7	5.5	4.6	6.2
Leaf blade length (cm)	1.8	9	8.4	4.2	9.8	1	10.4	9.8	8	10.7	0.8	8.6	8.8	7.6	10.2
Leaf blade width (cm)	0.2	4.9	4.9	4.5	5.1	0.6	6	5.8	5	6.8	0.4	6	6	5.5	6.8
Pod pedicel length	0.1	0.3	0.3	0.2	0.4	0	0.3	0.3	0.2	0.3	0.1	0.4	0.3	0.2	0.4
Pod length (cm)	0.3	5.4	5.4	5	5.8	0.7	6.3	5.9	5	6.6	0.5	6.5	6.3	5.7	6.9
Pod width	0.1	0.4	0.4	0.3	0.6	0.1	0.6	0.6	0.4	0.7	0.1	0.5	0.5	0.4	0.6
Number of pods per plant	5	8	10	4	18	7.9	12	12.9	2	28	8	8	10.2	0	26
Area of leaf	3.3	32.9	31.6	24.2	34.7	8	40.9	39.3	27.4	49.8	6.5	36.3	37.6	29.4	50
Area of pods	0.3	3.4	3.4	2.9	3.9	0.5	3.7	3.5	2.7	4	0.3	3.5	3.5	3.1	3.9
Days to 50% flowering "Day"	2.3	85	84.8	81	88	2.3	69	68.8	65	72	2.3	90	89.8	86	93
Characteristics	**SA-M-Yam**					**SA-Qat**					**SA-Mad**				
	ST	MEDIAN	MEAN	MIN	MAX	ST	MEDIAN	MEAN	MIN	MAX	ST	MEDIAN	MEAN	MIN	MAX
Plant height (cm)	21.2	58	61.8	34	90	17.1	71	64.7	33	85	30.8	108	100.2	45	163
Leaf petiole length(cm)	0.9	6	5.7	4.5	7	1.1	8	7.7	6	9.2	0.9	5.3	5.5	4.4	7.6
Leaf blade length (cm)	1.2	8.8	9.1	7.6	11.2	0.8	10.8	10.7	9.6	11.8	0.8	9.1	9.1	8.2	10.3
Leaf blade width (cm)	0.6	5.2	5.1	4.2	6	0.5	6	6.3	5.8	7	0.4	5.2	5.1	4.5	5.8
Pod pedicel length	0.1	0.3	0.3	0.2	0.4	0.1	0.3	0.3	0.2	0.4	0	0.3	0.3	0.3	0.4
Pod length (cm)	0.4	6	5.9	5.4	6.4	0.8	4.8	4.7	3.5	5.7	0.9	6.8	6.6	5.2	7.8
Pod width	0.1	0.5	0.5	0.4	0.6	0.1	0.5	0.5	0.3	0.6	0.1	0.4	0.4	0.3	0.5
Number of pods per plant	7.8	7	10.7	3	25	7.8	10	10.9	0	21	8.3	7	7.8	0	28
Area of leaf	8.9	29.5	33.8	22.8	46.3	5.9	43.9	44.8	37.9	54	4.8	32.2	32.6	26.4	38
Area of pods	0.4	3.4	3.3	2.9	3.8	0.7	2.8	2.7	1.5	3.4	0.4	3	3.1	2.6	3.8
Days to 50% flowering "Day"	2.3	69	68.8	65	72	2.3	90	89.8	86	93	2.3	85	84.8	81	88
Characteristics	**SA-Tai**					**SA-Lay**					**India**				
	ST	MEDIAN	MEAN	MIN	MAX	ST	MEDIAN	MEAN	MIN	MAX	ST	MEDIAN	MEAN	MIN	MAX
Plant height (cm)	10	112	109.8	88	120	8.5	112	113.4	104	130	29	114	108.9	49	147
Leaf petiole length(cm)	0.3	4.2	4.3	3.9	4.9	0.8	6.5	6.3	4.9	7.5	0.8	7.2	7.2	6.2	8.5
Leaf blade length (cm)	0.9	10	10.1	8.7	11.6	0.6	9.1	8.9	7.9	9.7	1.3	10	10	8	12
Leaf blade width (cm)	0.3	4.5	4.6	4.2	5.2	0.3	5.2	5.1	4.7	5.5	0.6	5.4	5.7	5.1	6.8
Pod pedicel length	0.1	0.2	0.3	0.2	0.4	0.1	0.3	0.3	0.1	0.4	0.1	0.3	0.3	0.2	0.4
Pod length (cm)	0.3	6.9	7	6.6	7.5	0.4	5.8	5.8	5.2	6.3	0.5	6.3	6.3	5.4	7
Pod width	0.1	0.4	0.4	0.3	0.6	0.1	0.5	0.5	0.4	0.6	0.1	0.5	0.5	0.4	0.6
Number of pods per plant	5.1	17	18.6	12	28	4.2	12	12.4	7	19	11.6	7	12.2	0	32
Area of leaf	5.4	29.9	30.3	23.3	38.7	44	34.1	59.8	27.3	136	9.7	37.8	42.1	32.3	60.9
Area of pods	0.1	3.8	3.8	3.7	4	0.4	3.5	3.4	2.7	3.7	0.4	4.1	4.1	3.5	4.5
Days to 50% flowering " Day"	2.3	69	68.8	65	72	2.3	83	82.8	79	86	2.3	69	68.8	65	72
Characteristics	**China**					**Japan**					**Libya1**				
	ST	MEDIAN	MEAN	MIN	MAX	ST	MEDIAN	MEAN	MIN	MAX	ST	MEDIAN	MEAN	MIN	MAX
Plant height (cm)	20.8	100	104.6	78	140	9.8	53	55	38.5	74	14	75.5	80.4	62	107
Leaf petiole length(cm)	0.8	6.5	6.3	4.5	7.5	0.7	4	4.3	3.6	5.8	0.4	4	3.9	3	4.3
Leaf blade length (cm)	1.2	9.1	8.9	7.2	11	1	7.3	7.6	6.4	9	0.5	10.5	10.4	9.5	11.1
Leaf blade width (cm)	0.7	5.2	5.2	4	6.2	0.3	4	4	3.5	4.5	0.2	4.9	4.9	4.7	5.2
Pod pedicel length	0.1	0.3	0.3	0.1	0.4	0	0.3	0.3	0.2	0.3	0.1	0.3	0.4	0.3	0.5
Pod length (cm)	0.5	5.3	5.5	4.9	6.2	0.7	5.2	5.1	3.8	5.7	0.6	5.5	5.5	4.5	6.3
Pod width	0.1	0.5	0.5	0.4	0.7	0	0.5	0.5	0.4	0.5	0.1	0.6	0.6	0.4	0.7
Number of pods per plant	3.7	6	7	2	14	6.6	11	13.9	7	29	7.7	9	12.2	3	25
Area of leaf	10.3	34.7	34.5	20	53.1	4.2	19.2	20.6	15.8	28.3	2.6	34.6	34.8	30.8	39
Area of pods	0.4	2.8	2.8	2.3	3.3	0.4	2.9	2.7	2	3.1	0.6	3.4	3.3	2.3	4
Days to 50% flowering " Day"	2.3	76	75.8	72	79	2.3	62	61.8	58	65	2.3	76	75.8	72	79

Table S4: (*Continued*)

Characteristics	SA-Giz					SA-Raf					SA-M-Muz				
	ST	MEDIAN	MEAN	MIN	MAX	ST	MEDIAN	MEAN	MIN	MAX	ST	MEDIAN	MEAN	MIN	MAX
Characteristics	Libya2					Libya3					Libya4				
	ST	MEDIAN	MEAN	MIN	MAX	ST	MEDIAN	MEAN	MIN	MAX	ST	MEDIAN	MEAN	MIN	MAX
Plant height (cm)	8.7	62	63.3	46	77	16.7	68	62.2	40	92	12.1	68	67.6	40	89.5
Leaf petiole length(cm)	0.2	4.3	4.2	3.9	4.6	0.4	1.9	2	1.7	3	0.7	4.6	4.8	3.9	6.2
Leaf blade length (cm)	1	8	8	6.5	9.2	0.6	7.2	7.1	6	7.9	0.5	8.5	8.4	7.4	9.1
Leaf blade width (cm)	0.6	4.6	4.6	3.8	5.5	0.2	4.1	4.1	3.7	4.4	0.4	5	4.8	4	5.3
Pod pedicel length	0.1	0.3	0.3	0.2	0.4	0.1	0.3	0.3	0.2	0.4	0.1	0.2	0.2	0.1	0.3
Pod length (cm)	0.4	5	4.8	4.2	5.2	0.3	4.1	4	3.5	4.4	0.4	5.6	5.8	5.2	6.4
Pod width	0.1	0.5	0.5	0.3	0.6	0.1	0.5	0.5	0.4	0.6	0.1	0.5	0.5	0.4	0.6
Number of pods per plant	7.5	16	18.8	9	32	7.5	14	13.1	1	27	7.9	21	20.1	5	30
Area of leaf	19.5	26.4	34.9	17.4	71.3	2.6	23.4	22.6	19.1	26	5.2	28.1	28.4	20.9	38.4
Area of pods	0.2	2.5	2.4	2.1	2.6	0.3	2.3	2.3	1.9	2.8	0.1	3.5	3.5	3.2	3.7
Days to 50% flowering " Day"	2.3	64	63.8	60	67	2.3	62	61.8	58	65	2.3	55	54.8	51	58
Characteristics	Tunisia1					Tunisia2					Tunisia3				
	ST	MEDIAN	MEAN	MIN	MAX	ST	MEDIAN	MEAN	MIN	MAX	ST	MEDIAN	MEAN	MIN	MAX
Plant height (cm)	6.5	62.5	62.7	50	75	5.1	60	59.8	50	68	10.3	49	53.1	37	69
Leaf petiole length(cm)	0.8	4.1	3.8	2.7	5	0.5	3	3	2.1	3.6	0.5	3.3	3.2	2.5	4
Leaf blade length (cm)	1	8.6	8.7	7.3	9.9	0.4	8.1	8	7.6	8.5	1	8.1	7.7	6	9.3
Leaf blade width (cm)	0.4	4.5	4.7	4.2	5.2	0.3	4.2	4.2	3.7	4.6	0.4	4.1	4.1	3.6	4.9
Pod pedicel length	0	0.2	0.2	0.2	0.3	0.1	0.3	0.3	0.1	0.5	0.1	0.3	0.3	0.1	0.4
Pod length (cm)	0.5	5.1	5.3	4.8	6	0.3	5.3	5.4	5.1	5.9	0.6	4.2	4.6	3.9	5.5
Pod width	0	0.4	0.4	0.3	0.4	0	0.5	0.5	0.5	0.6	0	0.4	0.4	0.3	0.4
Number of pods per plant	3	12	12.2	8	18	3.3	11	12.3	9	20	4.1	11	12	5	19
Area of leaf	7.9	26.7	29.8	18.8	42.6	3.6	21.7	22.3	18.5	30.5	6	22.5	22.5	15.1	34.5
Area of pods	0.3	3	2.9	2.5	3.2	0.2	3.1	3.1	3	3.4	0.5	2.2	2.4	1.8	3
Days to 50% flowering " Day"	2.3	48	47.8	44	51	2.3	48	47.8	44	51	2.3	55	54.8	51	58
Characteristics	USA					Egypt1					Egypt2				
	ST	MEDIAN	MEAN	MIN	MAX	ST	MEDIAN	MEAN	MIN	MAX	ST	MEDIAN	MEAN	MIN	MAX
Plant height (cm)	8	127.5	130.1	122	146	10.8	60	58.4	45	72.5	28	132	124.8	74	155
Leaf petiole length(cm)	0.8	7	6.7	5.1	7.5	1.1	4.6	4.9	3.6	6.2	1.2	6.5	7.1	5.8	8.8
Leaf blade length (cm)	1	9.4	9.1	7.7	10.5	1.2	8.1	7.7	6.1	9.2	1	9.1	9.4	8	11.1
Leaf blade width (cm)	0.7	5.4	5.4	4.1	6.1	0.5	4.7	4.5	3.7	5	0.7	5.4	5.6	4.6	7
Pod pedicel length	0	0.3	0.3	0.2	0.3	0	0.2	0.2	0.2	0.3	0	0.3	0.3	0.2	0.3
Pod length (cm)	0.7	6.3	6.5	5.8	7.7	0.5	5.6	5.6	4.9	6.4	0.9	6.2	6.1	4.7	7
Pod width	0	0.6	0.6	0.5	0.6	0	0.5	0.5	0.5	0.6	0.1	0.6	0.5	0.4	0.6
Number of pods per plant	5.3	18	18	9	27	6.3	16	16.7	6	30	6.7	17	15.6	3	24
Area of leaf	7.6	38.8	36.1	24.6	45.6	5.8	26.2	24.2	15.8	32.4	8.9	35.5	38	25.9	53.9
Area of pods	0.5	3.8	3.8	3.1	4.7	0.6	3.2	3.2	2.6	4.2	0.5	3.6	3.5	2.6	4.3
Days to 50% flowering " Day"	2.3	83	82.8	79	86	2.3	62	61.8	58	65	2.3	83	82.8	79	86
Characteristics	Egypt3					Egypt4					Egypt5				
	ST	MEDIAN	MEAN	MIN	MAX	ST	MEDIAN	MEAN	MIN	MAX	ST	MEDIAN	MEAN	MIN	MAX
Plant height (cm)	24.1	142	128.9	73.5	150	18.4	111	116.9	85	146.5	19.1	117	125.2	102	163
Leaf petiole length(cm)	0.6	6.6	6.4	5.6	7	0.3	6	5.9	5.3	6.4	0.6	5.5	5.5	4.6	6.4
Leaf blade length (cm)	0.7	9.2	9	7.9	10	0.5	8.5	8.5	7.6	9.1	0.8	8.4	8.4	7	9.4
Leaf blade width (cm)	0.3	5.6	5.4	5	5.8	0.3	5.1	5.1	4.6	5.6	0.4	4.9	4.8	4.1	5.4
Pod pedicel length	0	0.3	0.3	0.2	0.3	0.1	0.1	0.2	0.1	0.3	0.1	0.4	0.4	0.2	0.5
Pod length (cm)	0.5	6.3	6.5	6	7.3	1	6.4	6.3	4.6	7.9	0.2	6.2	6.3	6	6.7
Pod width	0.1	0.5	0.5	0.4	0.7	0.1	0.5	0.5	0.3	0.7	0.1	0.6	0.6	0.5	0.7
Number of pods per plant	12.8	16	19.9	1	47	4.9	9	11.2	7	24	13	14	18.4	4	41
Area of leaf	6	37	36.2	28.7	45.6	3.7	31.5	30.8	25	35.4	4.6	31	29.4	22.7	34.9
Area of pods	0.5	3.7	4	3.6	4.7	0.9	4	4.2	2.8	5.5	0.2	4.4	4.3	3.9	4.5
Days to 50% flowering " Day"	2.3	79	78.8	75	82	2.3	79	78.8	75	82	2.3	80	79.8	76	83