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Nutritional profile of cultivated and wild jute (*Corchorus*) species

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Abstract

Traditionally jute is cultivated for bast (phloem) fibre production. But in rural belts of Asian, African and European countries, tender leaves from young jute plants are consumed as green leafy vegetable. With a view to have knowledge of nutritional aspect of jute leaf, an experiment was conducted with 17 genotypes belonging to six jute species namely, *Corchorus fascicularis*, *C. trilocularis*, *C. aestuans*, *C. tridens*, *C. capsularis* and *C. olitorius*. These genotypes were assessed for growth (leaf area, foliage yield) and nutritional (crude protein, potassium, iron and β-carotene content) parameters. *C. olitorius* genotypes were found to be best performer for all the parameters except iron content, for which *C. aestuans* outperformed others. *C. olitorius* cv. JRO-204 had highest leaf area (23.9 x 10^{-4} m^2) and foliage yield (276.67 kg/ha) *vis a vis* good amount of protein (3.79%), iron (67.93 mg/kg), β-carotene (51.0 mg/kg) and potassium (4400 mg/kg). High heritability coupled with high genetic advance was found for all the parameters which indicate that these traits are governed by additive type of gene action; hence selection may be effective for improvement of these traits. The leaf and foliage yield were found to have significant positive phenotypic correlation with potassium content (0.85**, 0.82**), respectively. 17 genotypes were grouped into 4 clusters using Tocher method of clustering. Cluster-I is the largest cluster with 12 genotypes. The maximum inter-cluster distance (4748.20) was recorded between cluster-III and cluster-IV which indicates wider genetic diversity between the genotypes of these groups.

Keywords: Jute, Leafy vegetable, Iron, Protein, β-Carotene, Heritability, Variability.
Abbreviations: PCV_phenotypic coefficient of variation, GCV_ genotypic coefficient of variation, GA_genetic advance.

Introduction

Leaves along with petiole and soft stem from a wide range of plants are consumed as a leafy vegetable. They play important roles in human diets due to their ability to supply protein, energy, minerals, vitamins and certain hormone precursors (Antia et al., 2006). Among these, indigenous leafy vegetables enjoy special importance in human diets of Asia and Africa as they can be grown easily under harsh environmental condition through subsistence crop management practices which are prevalent in the region. Moreover, indigenous leafy vegetables are fairly easy to cultivate in terms of pest and disease control while producing very stable yields even under difficult climatic conditions (Cunningham, 1992). Besides, they are associated with health advantages. Nevertheless, in remote rural settlements where vegetable cultivation is not practiced and market supplies are not organized, local inhabitants depend on indigenous leafy vegetables for enriching the diversity of food. Hence, popularisation and cultivation of indigenous leafy vegetables is essential not to allow resource-poor farmers to produce food, but also to create jobs and to ensure healthier lives for themselves, their families and their community. Paradoxically, promotion over the years of only a small number of crops have systematically replaced the many indigenous crops traditionally planted and consumed by local subsistence farmers. The use of indigenous vegetables is declining in all areas in Asia, and the material and knowledge of its use are disappearing at an alarming rate. Therefore in the larger perspective of national and regional food security, usefulness and nutritional values of indigenous leafy vegetable like jute (*Corchorus* spp.) is required to be rediscovered and establish on scientific ground. The genus *Corchorus* which contains 40-100 species of flowering plants in the family Sparrmanniaceae, are known for bast fibre production (Heywood, 2007). Besides, few species of *Corchorus* with short and branched stems along with leaves are widely used as a leafy vegetable in many Asian, African and European countries (Furumuto et al., 2002; Velempini, 2003; Oyedele, 2006). In India, leaves of *C. olitorius* and *C. capsularis* are being used as vegetable in jute growing area as a by-product of thinning of jute field. Previous research findings indicated that edible species of *Corchorus* are very good source of proteins, vitamins (A, C, E) and they are also rich in mineral nutrients like calcium and iron (Steyn et al., 2001; Dansi et al., 2008). Moreover, *Corchorus olitorius* is known to contain high levels of iron and folate which are useful for the prevention of anaemia (Steyn et al., 2001). Besides nutrient superiority ecologically, the crop grows more easily in rural subsistence farming systems when compared to exotic species like cabbage and spinach (Modi et al., 2006). However, it is also the crop available during the spring season (April to June) when no other foliage crops can be grown in the field. Despite of its popularity as ‘pat sag’, very little is known about nutritional profile of *Corchorus* leaf especially in Indian context. Also, there is absolute lack of information on the qualitative improvement of foliage yield with special reference to nutritional parameters and association among themselves as well as with yield and leaf attributes. Therefore, to address these research gaps, the present investigation was undertaken to ascertain the nutritional composition of six *Corchorus* spp. and to find out possible ways for their enhancement.

Result and Discussion

In addition to their food and fibre value, different *Corchorus* species are used as medicinal plants (*C. olitorius*, *C. capsularis* and *C. aestuans* are used as general healers and a remedy for heart disease, enemas, parturition and febrifuges) and phyto-chemistry (*C. fascicularis* as soap and soap substitutes; *C. olitorius* as mucilage and source of fatty acid, oil and waxes; *C. capsularis* as source of glycosides, saponins and steroids) (Burkill, 2004). In this backdrop, analysing *Corchorus* leaf for nutritional parameters and establishing it as a potential indigenous green leafy vegetable is of paramount importance. The objective of the study was to assess and compare the various nutritional parameters in different strains of *Corchorus* spp., which are being widely consumed as a leafy vegetable in many parts of the world.

Nutritional comparison of *Corchorus* species

The analysis of variance revealed significant differences among the genotypes for all the six parameters, which validated further statistical analysis. Analysis of variance (ANOVA), mean performance and descriptive statistics of 17 genotypes of *Corchorus* spp. for nutritional and growth parameters are mentioned in Table 1.

Leaf area

The leaf area varied from 3.9 × $10^{-4}m^2$ (WCIN-012) to 23.9 × $10^{-4}m^2$(JRO-204) with an overall mean of 15.82 × $10^{-4}m^2$. JRO-204 had the largest leaf area (23.9 × $10^{-4}m^2$) followed by JRO-8432, Bidhan Rupali and KOM-62.

Foliage yield

JRO-204 (276.67kg/ha) recorded highest foliage yield followed by JRO-8432 (235.67 kg/ha) and S-19 (232.33 kg/ha) (Fig 1a). The mean foliage yield recorded was 666.71 kg/ha. For both leaf area and foliage yield, improved cultivars of *C. olitorius* has outperformed other *Corchorus* species accessions. This indicates that improved cultivars during manmade selection have gained higher biomass production ability in a limited time than the wild accessions. Hence, these cultivars can be directly grown by farmers as economically viable leafy vegetable.

Protein

For protein content, commercial varieties outperformed wild and other germplasm accessions in the study. Among varieties, KOM-62 (4.2%) had the highest protein content followed by JRO-3690 (4.14%) and JRO-524 (3.9%). The lowest amount of protein content was found in Sudan Green (3.16%). The mean protein content for 17 genotypes was 3.77%. Hence protein content can be improved through breeding programme. Bhargava et al. (2007) assessed 29 germplasm lines of quinoa (*Chenopodium quinoa* Willd.) for twelve morphological and seven quality traits. They reported high degree of morphological and qualitative variations among the lines. They found a very good range of seed protein content (12.55 to 21.02%) and seed carotenoid content (1.69–5.52 mg/kg) in quinoa.

β-Carotene

The *β*-carotene content among the genotypes ranged from 34.33-81.33 mg/kg with an average of 60.20 mg/kg. The highest amount of *β*-carotene was found in accession, Sudan Green (81.33 mg/kg) closely followed by Tanganyika (79.70 mg/kg) and *C. aestuans* accession, WCIN-009 (76.33 mg/kg). Gupta and Prakash (2009) reported the *β*-carotene content (mg/kg) of *Amaranthus* sp. (53.1), *Centella asiatica* (53.3), *Murraya koenigii* (84.4) and *Trigonella foenum graecum* (42.3). In present investigation it was found that most of the genotypes studied (except *C. trilocularis, C. tridens*, Bidhan Rupali, JRO-204, JRO-

Table 1. ANOVA, mean performance and descriptive statistics of 17 genotypes of *Corchorus* spp. for nutritional and growth parameters.

Sl. no	Species/accession/variety	Place of origin/pedigree	Leaf area ($\times 10^{-4} m^2$)	Foliage yield (kg/ha)	Crude Protein (%)	β-Carotene (mg/kg)	Iron (mg/kg)	Potassium (mg/kg)
ANOVA								
	MS (genotypes)		101.513**	11619.036**	0.164**	707.663**	2688.593**	125451.961**
Mean performance								
1	*C. fascicularis* (WCIN-034)	Tamil Naidu., India	8.87^{l}	86.33^{j}	3.60^{c}	62.67^{fg}	73.33^{e}	3903.33^{j}
2	*C. trilocularis* (WCIN-030)	Rajasthan, India	4.00^{m}	60.00^{k}	3.56^{c}	36.00^{j}	53.67^{h}	3900.00^{j}
3	*C. aestuans* (WCIN-009)	Odisha, India	10.17^{k}	98.33^{i}	3.75^{c}	76.33^{b}	184.07^{a}	4000.00^{i}
4	*C. tridens* (WCIN-012)	Rajasthan, India	3.90^{m}	56.33^{k}	3.74^{c}	47.00^{i}	69.00^{efg}	3850.00^{k}
5	*C. capsularis* (Maniksari)	West Bengal, India	13.53^{j}	141.67^{h}	3.86^{abc}	61.33^{g}	70.63^{ef}	4043.33^{h}
6	*C. olitorius* (Sudan Green)	Sudan, Africa	17.87^{g}	166.67^{f}	3.16^{d}	81.33^{a}	83.43^{d}	4253.33^{e}
7	*C. olitorius* (Tanganyika)	Tanzania, Africa	18.07^{fg}	177.33^{e}	3.56^{c}	79.70^{a}	103.40^{b}	4436.67^{b}
8	*C. olitorius* (TJ-40)	Selection from inter-mutant cross of JRO-632	16.63^{h}	161.00^{fg}	3.79^{bc}	64.00^{ef}	67.57^{fg}	4150.00^{g}
9	*C. olitorius* (Bidhan Rupali)	Mutant of JRO 632	20.08^{c}	232.33^{b}	3.73^{c}	34.33^{j}	86.53^{cd}	4163.33^{g}
10	*C. olitorius* (KOM-62)	Mutant of JRO-878	20.06^{c}	205.33^{c}	4.20^{a}	63.67^{efg}	65.17^{g}	4336.67^{d}
11	*C. olitorius* (JRO-66)	Multiple crosses	18.16^{f}	184.00^{de}	3.80^{bc}	67.33^{d}	82.77^{d}	4140.00^{g}
12	*C. olitorius* (JRO-3690)	Tobacco leaf ×Long internode	15.52^{i}	153.67^{g}	4.14^{ab}	66.00^{de}	51.27^{h}	4336.67^{d}
13	*C. olitorius* (JRO-8432)	IC 15901 × Tanganyika 1	20.41^{b}	235.67^{b}	3.85^{abc}	72.67^{c}	89.77^{c}	4473.33^{a}
14	*C. olitorius* (JRO-204)	IDN/SU/053 × KEN/DS/060	23.90^{a}	276.67^{a}	3.79^{bc}	51.00^{h}	67.93^{fg}	4400.00^{c}
15	*C. olitorius* (JRO-524)	Sudan green × JRO 632	19.90^{c}	205.67^{c}	3.90^{abc}	74.00^{bc}	71.80^{ef}	4333.33^{d}
16	*C. olitorius* (JRO-632)	Selection from germplasm	18.78^{e}	190.00^{d}	3.88^{abc}	35.33^{j}	70.27^{ef}	4460.00^{ab}
17	*C. olitorius* (S-19)	(JRO 620 × Sudan Green) × Tanganyika 1	19.11^{d}	203.00^{c}	3.87^{abc}	50.67^{h}	100.13^{b}	4216.67^{f}
	Mean		15.82	166.71	3.77	60.20	81.81	4199.80
	SEm		0.09	2.54	0.13	0.82	1.61	12.70
	Range		3.90- 23.90	56.33-276.67	3.16-4.20	34.33-81.33	51.27-184.07	3850.00-4473.33
	CV (%)		0.97	2.65	6.17	2.37	3.42	0.52
	LSD (5 %)		0.256	7.340	0.387	2.368	4.651	36.587

** significant at 1% level of probability a,b,c,d superscript over mean of each trait indicates multiple comparison of mean performance using t-test (LSD) at 5% level of probability.

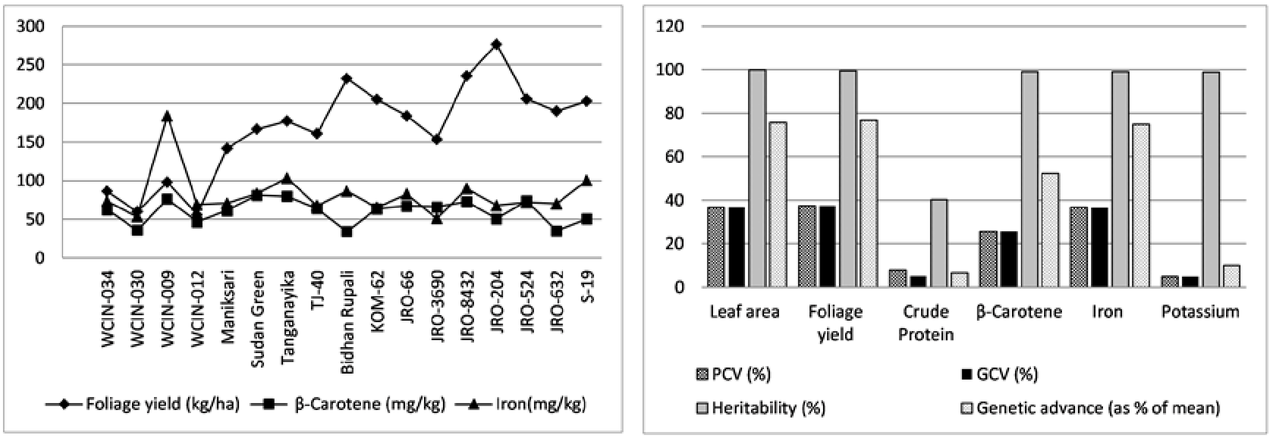

Fig 1. (a) The *per se* performance and (b) selection indices for growth and nutrient parameters of six *Corchorus* spp.

632, S-19) have higher amount of *β*-carotene content as compared to *Amaranthus* sp. and *Centella asiatica.* Moreover, *C. olitorius* accessions from Africa were found to have higher *β*-carotene content as compared to indigenous tossa jute (*C. olitorius*) cultivars.

Iron

The best performer for iron content was found to be *C. aestuans* accession, WCIN-009 (184.07 mg/kg) followed by Tanganayika (103.40 mg/kg) and S-19 (100.13 mg/kg). The mean estimate for iron content was 81.81 mg/kg. Interestingly, improved cultivars of *C. olitorius* recorded lower iron content compared to wild accession of *C. aestuans.* Hence, to improve iron content, *C. aestuans* can be used as source parent in future breeding programme.

Potassium

JRO-8432 (4473.33 mg/kg) had the highest potassium content followed by JRO-632 (4460 mg/kg). The lowest amount of potassium was found in *C. tridens* (3850 mg/kg). The improved cultivated tossa jute varieties out yielded other five *Corchorus* spp. over majority of nutritional parameters. Variety, JRO-524 which accounts for more than 90% of jute growing area in India, found to have high foliage yield (205.67 kg/ha) and is a good source of protein, iron, potassium and *β*-carotene. The relatively higher levels of protein, iron and *β*-carotene in the leaves of these species indicates the importance of these as vegetable. Iron content in jute leaf is higher than eggplant and spinach leaf (Shahid, et al., 2009). Genotypes namely, Tanganayika, WCIN-009 and S-19 recorded more amount of iron, potassium and *β*-carotene. However, comparison of *C. olitorius* with other *Corchorus* spp. shows that *C. aestuans* is a better source of iron and *β*-carotene but was poor foliage yielder with low leaf area. Hence, *C. aestuans* could be utilized as a donor parents for introgression of genes in iron and *β*-carotene deficient lines which otherwise exhibited high foliage yield potential. Ndlovu and Afolayan (2008) did nutritional analysis of *C. olitorius* leaf and compared it with spinach and cabbage. They found that *C. olitorius* leaf was better in Mg content than spinach and cabbage. The *C. olitorius* leaf reported to have phytate content lower than spinach and more iron and Zn content in comparison to cabbage.

Selection indices (Genetic parameters)

The amount of variability and extent of diversity for a particular trait in a crop species determine the limits of selection for improvement. The characters of economic importance are generally quantitative in nature and exhibit considerable degree of interaction with the environment. Thus, it becomes necessary to have variability estimates for the material being used in breeding programme. The values of phenotypic coefficient of variability (PCV) for growth and nutrient parameters were greater than the corresponding genotypic coefficient of variability (GCV) values, though in many cases the differences were very small. Leaf area, foliage yield, iron content and *β*-carotene content showed high coefficient of variation, while crude protein and potassium content exhibited low estimates of GCV and PCV values (Table 2). The heritability is the heritable portion of variability which is transmitted from parents to offspring. The effectiveness of heritability estimates is increased when they are used in association with the selection differential and genetic advance (Johnson et al., 1955). Burton (1952) suggested that GCV along with heritability estimates assist in understanding the amount of advance to be expected from selection. As suggested by Robinson (1965), heritability values can be categorized as low (5-10%), moderate (10-30%) and high (>30%). The heritability estimates were high for both growth and nutritional parameters (Fig. 1b). All parameters have heritability estimates ~99% except crude protein content. Except crude protein content and potassium content, rest of the parameters showed high estimates of GA. Among them foliage yield ranked first (76.65%), followed by leaf area (75.71%) (Table 2). Since all the traits have high heritability coupled

Table 2. Selection indices for growth and nutritional parameters of six *Corchorus* spp.

Parameters	*PCV*	*GCV*	$h^2_{(bs)}$ (%)	*GA* (as % of mean)
Leaf area	36.78	36.77	99.90	75.71
Foliage yield	37.39	37.30	99.50	76.65
Crude protein (%)	7.98	5.06	40.20	6.61
β-Carotene content	25.59	25.48	99.10	52.26
Iron content	36.70	36.54	99.10	74.95
Potassium content	4.89	4.86	98.90	9.95

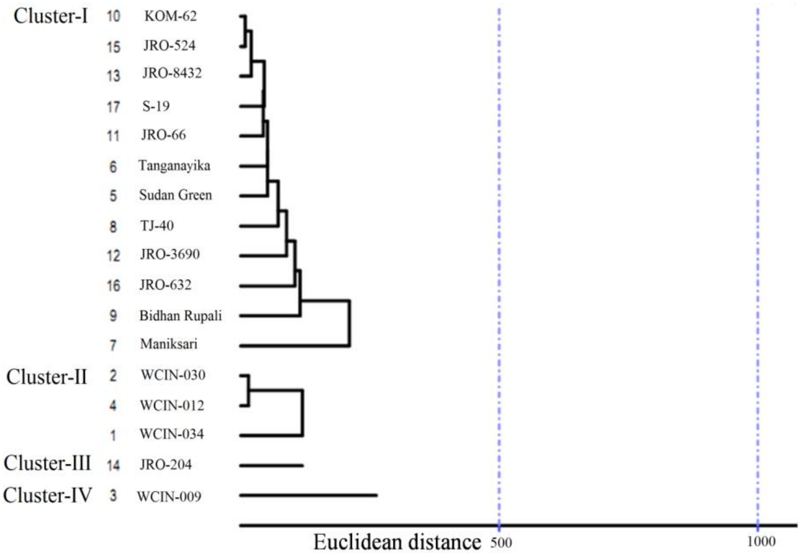

Fig 2. Dedrogram grouping 17 genotypes of *Corchorus* spp. in to four clusters based on Tocher method.

Table 3. Phenotypic correlation coefficients between different growth and nutritional parameters of six *Corchorus* spp.

Traits	Foliage yield	Crude protein	β-Carotene content	Iron content	Potassium content
Leaf area	0.972**	0.195	0.193	-0.034	0.855**
Foliage yield		0.206	0.055	-0.074	0.818**
Crude protein			-0.115	-0.146	0.210
β-Carotene content				0.366**	0.234
Iron content					-0.087

** Significance at 1% level of probability.

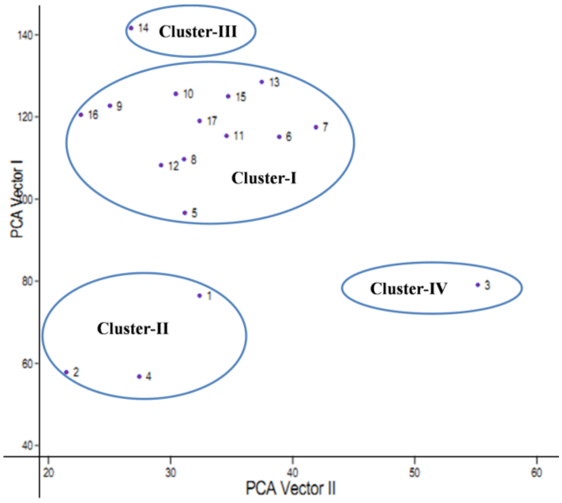

Fig 3. PCA plot of two vectors projecting 17 genotypes of *Corchorus* spp. into four clusters.

with high genetic advance which is due to additive type of gene action. So, selection will be effective and suitable method of breeding for improvement of these traits.

Correlation studies

Correlation analysis was done for undertaking selection of genotypes simultaneously for both growth and nutritional parameters (Table 3). Since all the genotypic correlations were non-significant, therefore only phenotypic associations are presented here. The perusal of association among parameters revealed that leaf area had highly significant positive correlation with foliage yield (0.972**) and potassium content (0.855**). Genotypes with more leaf area have more photosynthetic activity which in-turn resulted into high plant biomass production. Cervenski et al. (2012) noticed positive association of plant height and rosette diameter with whole plant weight, head weight, head height, and head diameter in the early genotypes of cabbage. Plant height and rosette diameter enhanced the active photosynthetic area in cabbages. In *Corchorus* spp. foliage yield also reported significant positive association with potassium content (0.818**). Iron content was positively correlated with β-carotene content (0.366**). So, selection and improvement for high iron content may indirectly lead to enhanced β-carotene content in a particular line. Garcia-Casal et al. (1998) reported that presence of vitamin A and β-carotene increased iron absorption in humans for rice, wheat and corn by preventing the inhibitory effect of phytates on iron absorption.

Principal component and cluster analysis

The method of genetic divergence has been successfully used for selected of diverse parents for hybridization programme in different crop species by different workers (Moll et al., 1962; Gizlice et al., 1996; Kaushik et al., 2007). Several measures of distance have been proposed over the years since the concept of genetic distance had been of vital utility in differentiating well defined populations (Arunachalam, 1981). Mahalanobis D^2 statistics which utilizes the Euclidean distance to compute genetic divergence (Mahalanobis, 1936 and Rao, 1952) has occupied a unique place in plant breeding hence most frequently utilized to assess genetic divergence.17 genotypes of different *Corchorus* spp. were subjected to canonical root analysis (principal component analysis). Based on the correlation matrix, eigen roots (eigen values) and eigen vectors were computed (Table 4). The first three components accounted for 98.75 per cent of the total variation. At 700.362 Tocher value, 17 genotypes were grouped into 4 clusters using Tocher method of clustering (Dendrogram, Fig. 2 & PCA plot, Fig. 3). Cluster-I is the largest cluster with 12 genotypes, all of which are of *C. olitorius* except Maniksari which belongs to *C. capsularis*. Cluster-II consists of 3 genotypes each of them belonging to different *Corchorus* species. Cluster-III and cluster-IV each had only single genotype *i.e.* JRO-204 and WCIN-009 (*C. aestuans).* The cultivated *Corchorus* spp. i.e. *C. olitorius* and *C. capsularis* are more closely related in all given parameters since they were grouped in same cluster whereas different genotypes of wild *Corchorus* spp. were found to be distributed in two different clusters. Unlike other wild species, *C. aestuans* accession (WCIN-009) placed separately in a different cluster since it is superior to other wild species in respect of both growth and nutritional parameters similarly JRO-204 grouped in a separate cluster because of its superiority over other cultivated lines wis-a-wis its parentage is different from rest of the *C. olitorius* genotypes which are more closely related to each other because of more or less similar ancestry. Cluster-I showed highest mean value for foliage yield and crude protein content, whereas, cluster-IV recorded highest mean for β –carotene content and iron content (Table 5).

Maximum intra-cluster distance (331.83) was exhibited by Cluster-II which have 3 genotypes each from different *Corchorus* spp. (Fig. 4) thereby depicting the diversity at species level. The minimum inter-cluster distance (803.72) was noticed between cluster-I and cluster-III since the genotypes of both of these belong to *C. olitorius* and are of cultivated. The maximum inter-cluster distance (4748.20) was recorded between cluster-III and cluster-IV which indicates wider genetic diversity between the genotypes of these groups; selection of parents from such clusters for hybridization programmes would help to create more variability for various component traits of leafy vegetable purpose. Shukla et al. (2010) evaluated 39 genotypes of vegetable amaranth (*Amranthus tricolor*) for 8 morphological (seed yield/plant, plant height, branches/plant, stem diameter, leaves/plant, leaf area, inflorescence length, 500-seed weight) and 7 quality traits (leaf moisture, chlorophyll a and chlorophyll b, crude protein, leaf carotenoid, ascorbic acid, fibre content) to assess the extent of genetic divergence. Cluster analysis grouped the 39 strains into six clusters which exhibited a wide range of diversity for most of the traits. In jute genetic diversity assessment using molecular markers viz., RFLP, AFLP, SSR, ISSR, RAPD, STMS (Saha et al., 2001; Basu et al., 2004; Roy et al., 2006) has been done earlier. Roy et al. (2006) assessed genetic diversity of exotic lines and commercial varieties of the two cultivated jute species (*C. olitorius* and *C. capsularis*) and two wild relatives, *viz*., *C. aestuans* and *C. trilocularis* using STMS, ISSR and RAPD markers. The markers show low level of intraspecific polymorphism. The wild species *C. aestuans* sub-clustered together with the accessions of *C. olitorius* whereas the *C. trilocularis* sub-clustered together with the *C. capsularis* indicating a polyphyletic origin of the two cultivated jute species.

Table 4. Eigen vectors, eigen roots and associated variation for first three principal components in *Corchorus* spp.

Parameters	Eigen vector		
	Vector 1	Vector 2	Vector 3
Leaf area	0.875	0.077	0.153
Foliage yield	0.174	-0.089	0.223
Crude Protein	0.156	-0.033	0.089
β-Carotene content	0.097	0.660	-0.707
Iron content	-0.155	0.741	0.646
Potassium content	0.383	0.010	-0.048
Eigen value (Root)	9911.657	1028.698	429.131
Variation (%) explained	86.090	8.935	3.727
Cumulative variation (%)	86.090	95.025	98.752

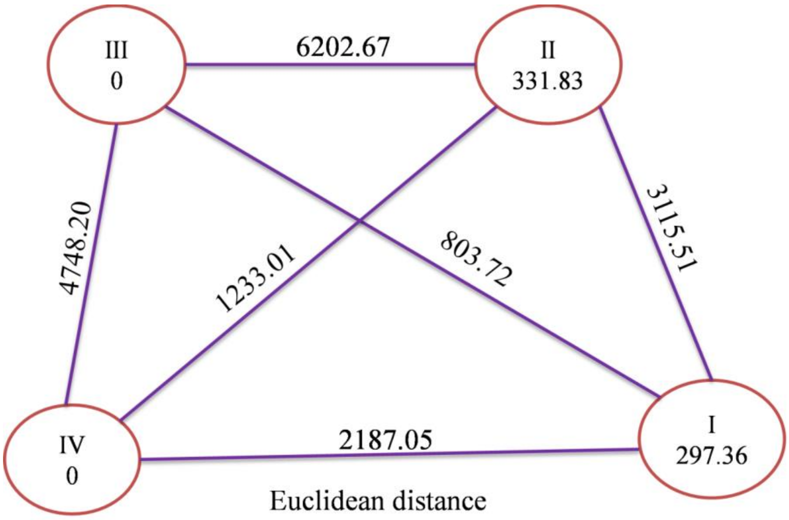

Fig 4. Cluster diagram depicting inter and intra-cluster Mahalanobis Euclidean distance between four clusters of *Corchorus* spp.

Materials and methods

Plant materials

The material consisted of 17 genotypes, belonging to six species of jute which includes one genotype each of *C. fascicularis* (WCIN-034), *C. trilocularis* (WCIN-030), *C. aestuans* (WCIN-009), *C. tridens* (WCIN-012), *C. capsularis* (Non bitter accession, Maniksari) and 13 genotypes of *C. olitorius* (Table 1). These 13 *C. olitorius* genotypes consists of two germplasm accessions *viz.*, Sudangreen and Tangnayika, three mutants namely; TJ-40, JRO-3690, Bidhan Rupali and 8 commercially released varieties *viz.*, KOM-62, JRO-66, JRO-3690, JRO-8432, JRO-204, JRO-524, JRO-632 and S-19. All six *Corchorus* spp. which used for the experiment have variation in the leaf morphology (Fig 5). All these 17 genotypes were evaluated during *spring* season, 2010 at experimental farm of Central Research Institute for Jute and Allied Fibres, Barrackpore, West Bengal in a Randomised Block Design with three replications. Each plot consisted of single row of 2 m with row to row distance of 30 cm. The plant to plant spacing was maintained at 5-7 cm by thinning after 15 days. The recommended intercultural operations were followed during the crop growth period. After 3rd week of sowing, whole plant foliage cutting done and data on foliage yield (kg) was recorded on plot basis and converted to per hectare basis. Ten plants per plot were randomly selected and their top five leaves were used for measurement of leaf area using digital leaf area meter.

Method of nutrient assessment

For nutritional analysis, fresh green leaves were harvested in early morning, packed in aluminium foil and transferred immediately into oven. Each of the samples was oven dried to a constant weight at 60°C. After drying, the plant materials were ground into fine powder with the mesh size of 0.5 mm and stored in well labelled air tight polythene bags at 4°C until further used. Crude protein content was determined using the Micro-Kjeldahl nitrogen method. The value of nitrogen was multiplied by 6.25 to obtain crude protein percentage (Antia, 2006). *β*-Carotene content of leaf were estimated by Spectrophotometric method as per Sadasivam and Manickam (1996) and expressed as mg/kg of leaf dry weight. Potassium content was determined by flame photometry, and iron was determined using atomic absorption spectrophotometer (Perkin Elmer 5100) (Vogel, 1962; AOAC, 1990).

Table 5. Cluster mean for different parameters of *Corchorus* spp.

Parameters	Cluster mean			
	Cluster-I	Cluster-II	Cluster-III	Cluster-IV
Leaf area (× 10^{-4} m^2)	18.18	5.59	23.90	10.17
Foliage yield kg/ha	188.03	67.56	276.67	98.33
Crude Protein (%)	3.81	3.63	3.79	3.75
β-Carotene(mg/kg)	62.53	48.56	51.00	76.33
Iron (mg/kg)	78.56	65.33	67.93	184.07
Potassium(mg/kg)	4278.61	3884.44	4400.00	4000.00

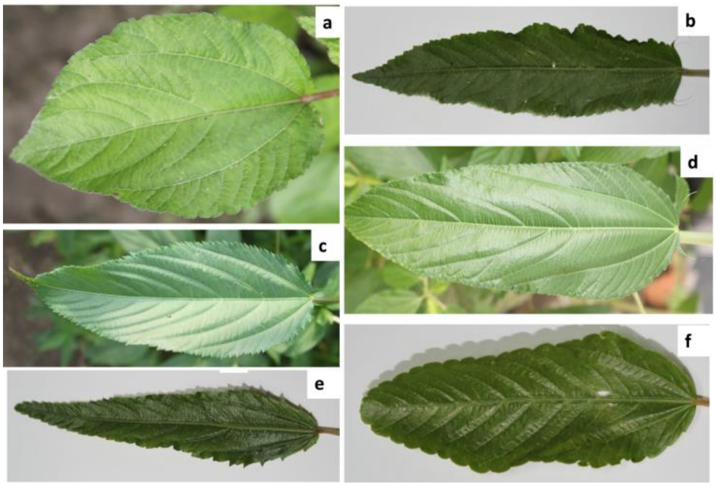

Fig 5. Variation for leaf morphology in six Corchorus spp. (a) *C. aestuans* (b) *C. tridens* (c) *C. capsularis* (d) *C. olitorius* (e) *C. fascicularis* (f) *C. trilocularis*.

Statistical analysis

The analysis of variance (ANOVA) was done as per Panse and Sukhatme (1985). Phenotypic and genotypic coefficients of variation were obtained as the ratio of respective standard deviation to the general mean of the characters and expressed in percentage following Burton and Devane (1953). Heritability in broad sense and expected Genetic Advance (GA) under selection were calculated following the method of Allard (1960). Genetic Advance (GA) as per cent of mean was calculated as suggested by Johnson et al. (1955).

GCV (%) $=\frac{\sqrt{\sigma 2g}}{\bar{X}} \times 100$

CV (%) $=\frac{\sqrt{\sigma 2g}}{\bar{X}} \times 100$

Heritability (h^2_b) % = $\frac{\sigma 2g}{\sigma 2p}$x 100

Expected genetic advance (GA) = $i\sigma_p h^2$

G.A. as % of mean $=\frac{\text{G.A.}}{\bar{X}} \times 100$

Where, σ^2_g: genotypic variance, σ^2_p: phenotypic variance, $\bar{X}$: general mean, *i*: standardized selection differential, a constant (2.06), σ_p: phenotypic standard deviation ($\sqrt{\sigma 2p}$)

Genotypic and phenotypic correlation coefficients were estimated as per Searle (1961) and the significance of correlation coefficients (r) was tested by comparing with *'t'* value at (n-2) *d.f.* (Snedecor and Cochran, 1967).

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}}$$

Principal component and cluster analysis were done using Mahalanobis' D square statistics programme of Plant Breeding pack of Windostat 9.1 statistical software which compute this analysis according to Rao (1952)

Conclusions

Most rural communities in India and other parts of Asia rely on vegetables as source of protein, iron and *β*-carotene; therefore, *Corchorus* spp. especially *C. olitorius* could play a significant role in for providing cheap and affordable protein for rural populations. The present study has identified two popular varieties namely, JRO-204 and JRO-8432 that have high foliage yield, protein, *β*-carotene and potassium content and can substantiate these nutrients in rich quantities in human diet that will help Indian population to fight against hunger and malnutrition especially in marginal and tribal belt of the nation where jute is grown.

In nut-shell, this study brings forth the nutritional superiority of jute leaf, especially *C. olitorius* which is presently underutilized in terms of consumption and trade, but offer exciting prospects for crop diversification and nutritional needs of the community.

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References

Allard RW (1960) Principles of plant breeding. John Wiley and Sons Inc., New York.

Antia BS, Akpan EJ, Okon PA, Umoren IU (2006) Nutritive and anti-nutritive evaluation of sweet potatoes (*Ipomoea batatas*) leaves. Pak J Nutr 5: 166-168

AOAC (1990) Official Methods of Analysis, 14th edition Washington, DC: Association of Official Analytic Chemists.

Arunachalam V (1981) Genetic distance in plant breeding. Ind J Genet 41(2): 226-236.

Basu A, Ghosh M, Meyer R, Powell W, Basak SL, Sen SK (2004) Analysis of genetic diversity in cultivated jute determined by means of SSR markers and AFLP profiling. Crop Sci 44: 678–685

Bhargava A, Shukla S, Rajan, S, Ohri D (2007) Genetic diversity for morphological and quality traits in quinoa (*Chenopodium quinoa* Willd.) germplasm. Genet Resour Crop Evol 54: 167–173

Burkill HM (2004) The useful plant of west tropical Africa, (2nd edn), vol 6, general index. Royal Botanical Gardens, Kew.

Burton GW (1952) Quantitative inheritance in grass. Proc Sixth Intern Grasslands Congr Vol. I. 277-283

Burton GW, Devane EM (1953) Estimating heritability in tall festuca from replicated clonal material. Agron J 45: 478-481

Cervenski J, Gvozdanovic-Varga J, Glogovac S (2012) Variance components and correlations of agronomic traits among cabbage (*Brassica oleracea* var. *capitata* L.) maturity groups**.** Genetika 44(1): 55-68

Cunningham AB, Jager PJ de, Hansen LCB (1992) The indigenous plant use programme. Foundation for Research Development, Pretoria.

Dansi A, Adjatin A, Adoukonou-Sagbadja H, Faladé V, Yedomonhan H, Odou D, Dossou B (2008) Traditional leafy vegetable and their use in the benin republic. Genet Resour Crop Evol 55: 1239-1256

Furumuto T, Wang R, Okazaki K, Hasan FA, Ali IM (2002) Antitumour promoters in leaves of jute (*Corchorus capsularis* and *Corchorus olitorius*). Food Sci Technol Res 8: 239-243

Garcia-Casal MN, Layrisse M, Solano L, Baron MA, Arguello F, Llovera D, Ramirez J, Leets I, Tropper E (1998) Vitamin A and beta-carotene can improve nonheme iron absorption from rice, wheat and corn by humans. J Nutr 128(3): 646-50.

Gizlice Z, Thomus E, Carter Jr, Gerig TM, Burton JW (1996) Genetic diversity patterns in North America public soybean cultivars based on coefficient of percentage. Crop Sci 36: 753-765.

Gupta S, Prakash J (2009) Studies on Indian green leafy vegetables for their antioxidant activity. Plant Foods Hum Nutr 64: 39–45

Heywood VH, Brummitt RK, Culham A, Seberg O (2007) Flowering plant families of the world. Royal Botanical Gardens, Kew

Johnson HW, Robinson HF, Comstock RE (1955) Estimates of genetic and environmental variability in soybean. Agron J 47: 314-318

Kaushik N, Kumar,K, Kumar S, Kaushik N, Roy S (2007) Genetic variability and divergence studies in seed traits and oil content of Jatropha (*Jatropha curcas L.*) accessions. Biomass Bioenergy 31(7): 497-502

Mahalanobis PC (1936) On the generalized distance in statistics. Proc Natl Inst Sci India 12:49-55

Modi M, Modi AT, Hendriks S (2006) Potential role for wild vegetables in household food security: A preliminary case study in Kwazulu-Natal, South Africa. Afr J Food Agri Nutr Develop 6: 1-13

Moll RH, Sathuna WS, Robinson HF (1962) Heterosis and genetic diversity in variety crosses of maize. Crop Sci 2: 197-198

Ndlovu J, Afolayan AJ (2008) Nutritional analysis of the South African wild vegetable *Corchorus olitorius.* Asian J Plant Sci 7(6): 615-1618

Oyedele DJ, Asonugho C, Awotoye OO (2006) Heavy metals in soil and accumulation by edible vegetables after phosphate fertilizer application. Elect J Agric Food Chem 5: 1446-1453

Panse VG, Sukhatme PV (1985) Statistical Methods for Agricultural Workers. N. Delhi, Indian Council of Agriculture Research.

Rao CR (1952) Advance statistical methods in biometrical research. Ed. II. New York. John Willey and Sons.

Robinson HF (1965) Quantitaive genetics in relation to breeding on the centennial of Mendelism. The impact of Mendelism on Agriculture, Biology and Medicine (Proceedings of 3rd International symposium to celebrate the centenary of Mendelism). Ind J Genet 26A: 171-187

Roy A, Bandyopadhyay A, Mahapatra AK, Ghosh SK, Singh NK, Bansal KC, Koundal KR, Mohapatra T (2006) Evaluation of genetic diversity in jute (*Corchorus* species) using STMS, ISSR and RAPD markers. Plant Breeding 125: 292—297

Sadasivam S, Manickam A (1996) Biochemical Methods (2nd edn.) New Age International Publisher, New Delhi, pp. 187-188

Saha T, Majumdar S, Banerjee NS, Sen SK (2001) Development of interspecific somatic hybrid cell lines in cultivated jute and their early characterization using jute chloroplast RFLP marker. Plant Breed 120: 439–444.

Searle SR (1961) Phenotypic, genotypic and environmental correlations. Biometrics 1**7**: 474-480

Shahidi F, Chavan UD, Bal AK, Mckenzie DB (1999) Chemical composition of beach pea (*Lathyrus maritimus* L.) plant parts. Food Chem 64: 39-44

Snedecor GW, Cochran WC (1967) Statistical Method. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi

Steyn NP, Olivier J, Winter P, Burger S, Nesamvuni S (2001) A survey of wild, green, leafy vegetables and their potential in combating micronutrient deficiencies in rural populations. S Afr J Sci 97: 276-279

Sudhir Shukla S, Bhargava A, Chatterjee A, Pandey AC, Mishra BK (2010) Diversity in phenotypic and nutritional traits in vegetable amaranth (*Amaranthus tricolor*), a nutritionally underutilised crop. J Sci Food Agric 90: 139–144

Velempini P, Riddoch I, Batisani N (2003) Seed treatments for enhancing germination in wild okra (*C. olitorius*). Exp Agric 39: 441-447

Vogel AT (1962) Quantitative inorganic analysis. London: Longmans.