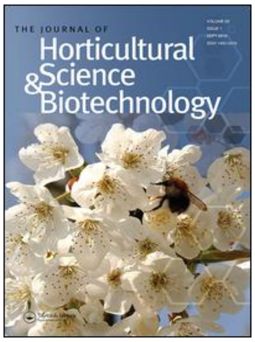

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The Journal of Horticultural Science and Biotechnology

ISSN: 1462-0316 (Print) 2380-4084 (Online) Journal homepage: http://www.tandfonline.com/loi/thsb20

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THE JOURNAL OF HORTICULTURAL SCIENCE AND BIOTECHNOLOGY, 2017
http://dx.doi.org/10.1080/14620316.2017.1304168

ARTICLE

Leaf and seed yield of jute mallow (*Corchorus olitorius* L.) accessions under field conditions for two consecutive growing seasons

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ABSTRACT

Jute mallow is a nutritious leafy vegetable used by many people in Africa. The purpose of this study was to select accessions with high leaf yield and seed yield. We investigated seven agronomic traits that are related to leaf yield and seed yield and how they correlate with each other. The results indicated significant differences among the accessions in all traits. Leaf fresh weight ranged from 18.3 to 121.3 g/plant in accessions TOT 6747 and TOT 8532, respectively. The highest variability between the accessions was also observed in seed yield. It ranged from 1.0 g/plant in accession TOT 7980 to 35.5 g/plant in TOT 7866. Eight other accessions had a seed yield of 1.0 g/plant. Significant and positive correlations were observed between leaf fresh weight and leaf dry weight (r = 0.84), leaf area (r = 0.33), and number of leaves (r = 0.40). A significant correlation was observed in seed yield and weight of pods per plant (r = 0.83). The evaluation of these agronomic traits for leaf and seed yield in this germplasm has revealed useful information for breeders in their efforts to improve the yield as well as selection of accessions with good agronomic traits.

ARTICLE HISTORY
Accepted 2 March 2017

KEYWORDS
Corchorus spp; jute mallow; germplasm; leaf area; leaf yield; seed yield

Introduction

Corchorus spp. are well known in the tropics where they are widely grown as vegetables for the viscosity of their leaves, either freshly prepared or sun dried. They represent some of the most popular tropical leafy vegetables in Africa, Asia, some parts of the Middle East, and Latin America (Adediran, Ibrahim, Tolorunse, Gana, 2015). The young leaves of many species with short and branched stems are widely used as leafy vegetables (Velempini, Riddoch, & Batisani, 2003). When boiled or cooked, the leaves produce mucilage, a property useful in making sauces to accompany coarse starchy foods (Benor, Blattner, Demissew, & Hammer, 2010).

Jute mallow (*Corchorus olitorius* L.), like other traditional leafy vegetables, represents cheap but quality nutrition for large segments of the population in urban and rural areas (Freiberger et al., 1998; Kinabo et al., 2006; Lewu & Mavengahama, 2010; Willem, Ineke, Van Zijl, & Sonja, 2007). Nutritionally, jute mallow leaves contain an average of 15% dry matter, 4.8 g of protein, 259 mg of calcium, 4.5 mg of iron, 4.7 mg of vitamin A, 92 µg of folate, 1.5 mg of nicotinamide, and 105 mg of ascorbic acid, per 100 g of leaves (Dansi et al., 2008; Grubben & Denton, 2004; Odhav, Beekrum, Akula, & Baijnath, 2007).

In many African countries, particularly Tanzania, commercial farming of jute mallow is practised to a very limited extent compared with other vegetables. However, for a long time, it has been semi-domesticated, and sometimes grown as a volunteer crop in farmers' fields and on fertile soils close to and around most homesteads (Mnzava, 1997). The status of jute mallow as a volunteer or wild plant renders it unappealing for consideration in crop development programs and is often seen as an orphaned crop. In Kenya, for instance, limited research identified jute mallow as a vegetable that could be developed for commercial production (K'opondo, Muasya, & Ok, 2005).

In order to improve the production of this vegetable in Tanzania, efforts must be directed towards the selection of promising accessions with good adaptation to the local enviroment and including them in breeding programmes for improvement of desirable traits. The most important aspect that will facilitate production relies on the ability of these accessions to produce a high amount of leaves, which is the harvestable part, as well as high seed yield for its propagation. A lack of seeds is reported as a problem limiting production of jute mallow (Opabode & Adebooye, 2005). Little information is reported on the availability of improved genotypes of jute mallow with good leaf and seed yield as well as with good adaptation to local environments.

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A number of studies on jute mallow in different environments have been conducted to assess the leaf yield and its components (Adediran et al., 2015; Fasinmirin & Olufayo, 2009; Makinde, Oluwole, Ojekale, & Olufeyemi, 2009; Olaniyi & Ajibola, 2008). Plant spacing and leaf harvesting frequency significantly affect leaf yield and seed yield (Madakadze, Kodzanayi, & Mugumwa, 2007). Aluko et al. (2014) observed that plants treated with fertiliser (2.5t/ha of organic fertiliser mixed with 75 kg of NPK) had thicker stems, more leaves, and more dry matter as compared to unfertilised plants. Similar results were reported by Adediran et al. (2015), who found that poultry manure significantly improved all growth parameters of jute mallow as compared with other nutrient sources. Successful production of jute mallow seeds is influenced by factors such as season of crop growth, disease incidence and severity, and difficult in drying fruit after harvest during rain (Tindall, 1965; Van Epenhuijsen, 1974).

In many studies conducted, the main focus has been the effect of environmental factors on yield of leaves and seeds. No information is available on selection of jute mallow for seed set ability. However, for the purpose of germplasm characterisation and selection of promising accesions adapted to the local environment, varietal or accession differences in leaf and seed production in a similar environment are crucial for meaningful selection.

The present study therefore aims to explore the variation in accessions in terms of leaf production and seeds, and then assess whether significant correlations exist between leaf yield and seed yield-related attributes.

Materials and methods

Study location and experimental material

Field experiments were carried out at World Vegetable Centre, Eastern and Southern Africa, based at Arusha, Tanzania. The experimental field was located at Madiira farm at an altitude of 1262 m above sea level, latitude 03.38°S and longitude 36.87°E. Experiments were carried out for two growing seasons, in 2015 and 2016 (from February to June). The soils are well drained. The monthly total rainfall and monthly average temperature during the growing season are presented in Figure 1.

The experimental materials comprised 90 accessions of jute mallow (*Corchorus olitorius* L.) provided by the seed repository of the World Vegetable Centre, Eastern and Southern Africa. These accessions originated from 14 countries: Tanzania, Cameroon, Malawi, Kenya, Uganda, Sudan, USA, Japan, Zimbabwe, Vietnam, Malaysia, Bangladesh, Philippines, and Taiwan. Six of these accessions were of unknown origins. The accessions represent a part of the centre's germplasm of different types of traditional vegetables that are locally grown by farmers.

Experimental design and layout

Seeds of each accession were sown in a separate plastic (PVC) tray with 66 holes (4 cm diameter and 4 cm height) using sterilised soil. The trays were kept in a screen house to raise the seedlings at a temperature of 27–30°C, and irrigated with a watering can twice a day. The relative humidity of the screen house, on average, was 80%. After 28 days, the seedlings were transplanted to the field. The plot size was 3 × 0.6 m with three replications in a randomised complete design. Each accession was planted in two rows, and the space between plants was 0.25 m with 12 plants per row. Fertiliser application was done 1 week after transplanting. Diamonium phosphate (DAP) at an application rate of 143.8kgP/ha and urea at an application rate of 55.2kgN/ha were used. The experiments were conducted during the rainy season; the plants were only supplemented with irrigation when necessary. Manual weeding was carried out regularly to maintain weed-free plots as well as spraying for pests and diseases.

Data collection and analysis

Five plants per plot were selected randomly, and the following data were recorded from them: number of

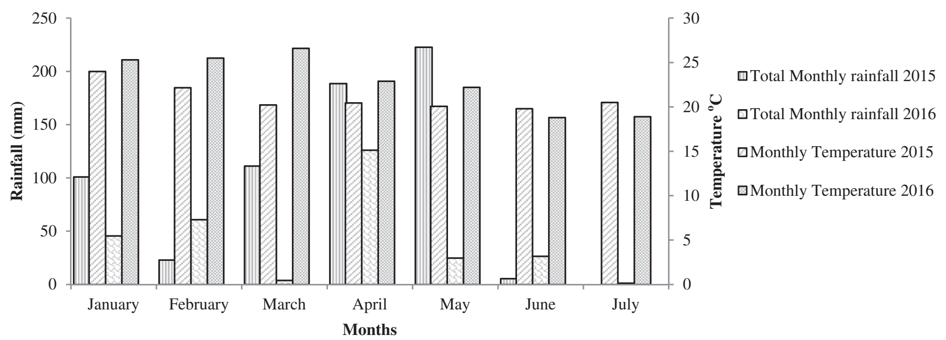

Figure 1. Meteorological data on monthly average temperature and total monthly rainfall during the two growing seasons.

leaves per plant (counted); leaf fresh weight (harvested simultaneously 3 times at intervals of 14–21 days); leaf dry weight (oven dried at 80°C for 24 hours until constant weight attained). Leaf moisture content was estimated using the following formula:

$$MC\% = \frac{\text{Leaf fresh weight} - \text{Leaf Dry weight}}{\text{Leaf fresh weight}} x100 \quad (1)$$

where MC = moisture content.

Other morphological characters examined included number of pods per plant (counted); weight of pods per plant; weight of seeds per plant; and measurement of leaf length and width for 10 leaves selected from the five plants, and averaged to one value, for the calculation of leaf area.

Leaf area was calculated according to Peksen (2007):

$$\text{LA} = 0.919 + 0.682\text{LW} \quad (2)$$

where LA = leaf area, L = leaf length, and W = leaf width.

The values for each of the five plants were averaged to get a single value for each plot. Then the average value for each plot in each replication for both seasons was calculated. This pooled mean of the two growing seasons from each plot was subjected to analysis of variance (ANOVA). Descriptive statistics, i.e. mean, minimum, maximum, and standard error, were calculated for the eight traits. The Pearson correlation method was used to compute correlation coefficients to investigate the degree of association between the traits. These computations were done using the statistical software program STATISTICA version 12, edition 2013 (Statsoft inc., Tulsa, OK, USA). Fisher's least significance was used to compare means at the $P = 0.05$ level of significance.

Results

Fresh weight and dry weight of leaves

The ANOVA results indicated significant ($p < 0.001$) differences among the accessions in all traits studied (Table 1). Leaf fresh yield was lowest in accession ML-JM-7 and highest in accession TOT 8532. Leaf dry weight was lowest in accession ML-JM-7 and highest in accession TOT 8532. Leaf area was lowest in accession TOT 9736 and highest in accession Bafia. The number of leaves per plant was lowest in TOT 6730 and highest in TOT 4051. The highest moisture content was found in accession Kipumbuliko, and TOT 4519 had lowest moisture content (Table 1).

The smallest leaf area (value given per leaf) among the top five accessions was observed in TOT 4051. This accession had the highest number of leaves compared with all other accessions in this study (Table 1). It was observed that most of the accessions with small leaves also contained many primary and secondary branches. Accessions with the highest leaf area were Bafia, TOT 7974, Aziga, TOT 8532, and Kipumbuliko (data not shown). These accessions had the lowest number of leaves (124, 272, 101, and 158, respectively), well below the average as compared with the rest of the accessions. These accessions had few primary and secondary branches. TOT 8532 was an exception; it had the highest number of leaves (623), well above the average for all accessions, and the highest yield of fresh leaves. Thus, the combination of a high number of leaves and large leaf area resulted in a high leaf yield. The accessions with the highest leaf yield among all those in the study are presented in Figure 2(a)–(e)).

Figure 3 shows five accessions with the highest leaf yields compared with all other accessions in this study. Figure 3(a) shows the five accessions with the highest fresh leaf yield. In Figure 3(b), the five accessions with the highest dry leaf yield are presented. Leaf yield in both figures was compared with the seed yield of the respective individual accessions. Accession GKK 25 produced the highest seed yield among the top five accessions in leaf yield; this seed yield was below the average seed yield of all accessions and statistically significantly different from the average seed yield.

Seed yield

Seed yield varied significantly across all accessions. TOT 7866 had the highest seed yield compared with all other accessions, while accession TOT 7980 had the lowest seed yield (Table 1). The other accessions with the lowest seed yield were TOT 4051, TOT 4631, TOT 0124, TOT 4708, TOT 3499, TOT4670, Kiumbuliko, and TOT 6730 (data not shown).

Figure 4 shows the five accessions with the highest seed and pod yields compared with all other accessions in this study. Figure 4(a) shows the five

Table 1. Descriptive statistics and analysis of variance of seven leaf and seed yield-related traits of the 90 accessions.

	Leaf fresh weight/plant	Leaf dry weight/plant	Leaf area (value per leaf)	Number of leaves/plant	Weight of pods/plant	Weight of seeds/plant	Number of pods	Moisture content (%)
Mean	50.68***	14.10***	44.66***	289.58***	19.53***	7.61***	112.24***	71.9**
Maximum	121.3	32.6	106.97	1089.67	55.03	35.53	430.33	80.6
Minimum	9.2	3.4	14.07	31.00	4.33	1.00	9.3	59.1
SE	1.24	0.39	1.07	11.42	0.79	0.39	6.49	0.40

** = significant at $P < 0.01$, *** = significant at $P < 0.001$.

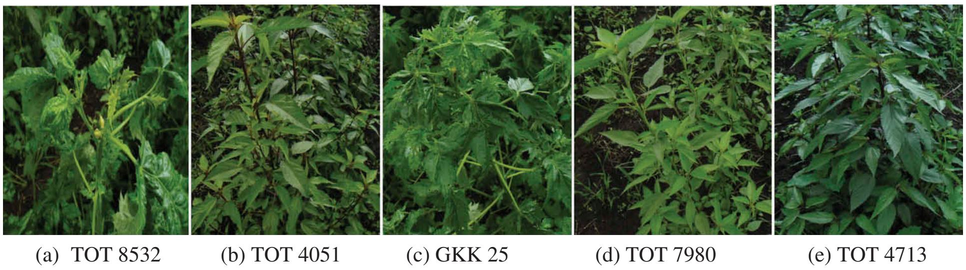

Figure 2. (a)–(e) Accessions with high leaf yield. (a) TOT 8532, (b) TOT 4051, (c) GKK 25, (d) TOT 7980, (e) TOT 4713.

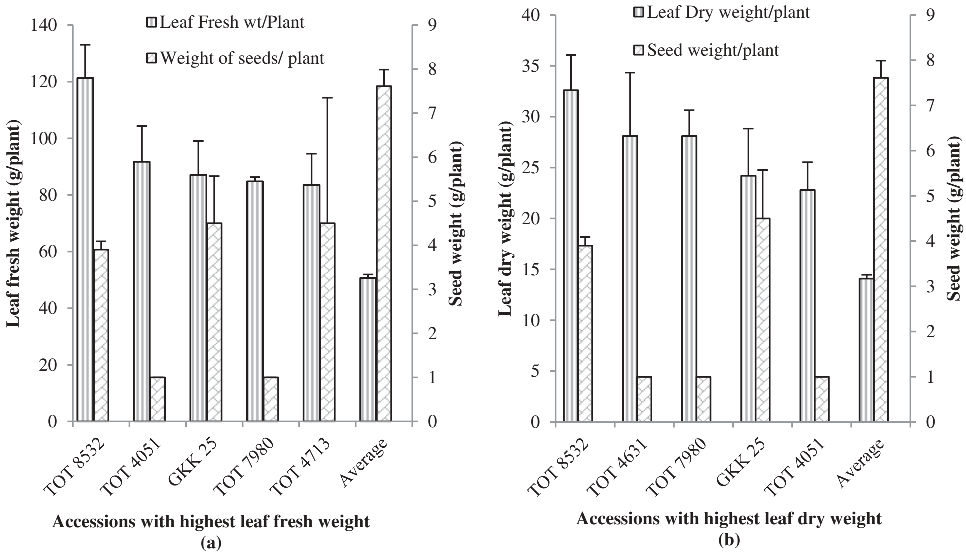

Figure 3. (a) Accessions with highest leaf fresh weight yield and their seed yield, and (b) accessions with highest dry weight and their seed yield.

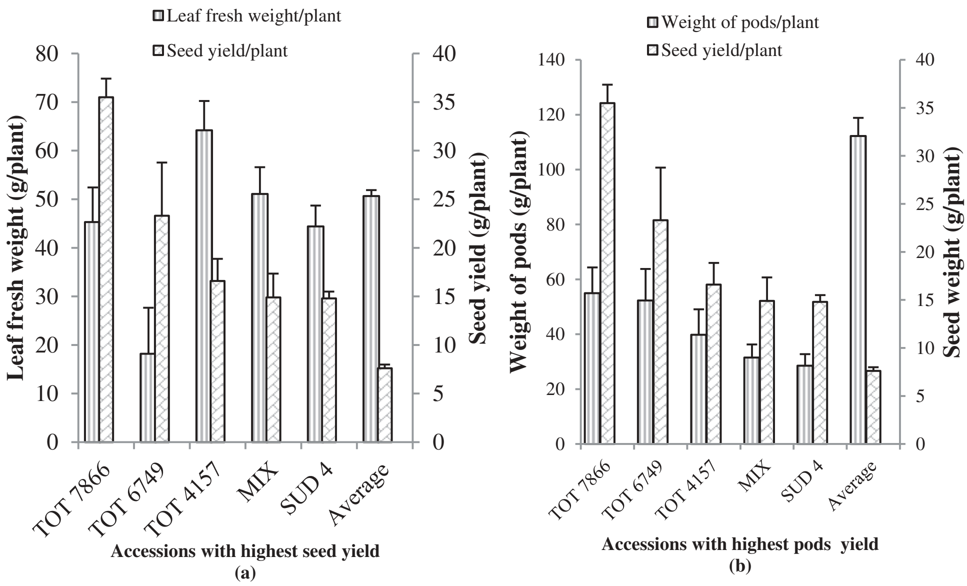

Figure 4. (a) Accessions with highest seed yield and their leaf fresh weight yield, and (b) accessions with highest dry weight and their seed yield.

accessions that had the highest seed yield. In Figure 4(b), the five accessions with the highest pod yield are presented. Seed yield is compared with leaf fresh weight in Figure 4(a), and in Figure 4(b) pod yield is compared with seed yield. The accessions that had the highest seed yield had low leaf yield, with three of them being well below the average leaf yield for all accessions (Figure 4(a)). Figure 4(b) shows that a high weight of pods is associated with high seed yield; i.e. the higher the pod weight the higher the seed yield.

Simple correlations between leaf and seed yield-related attributes

Fresh leaf yield per plant was significantly and positively (r = 0.84, < 0.01) correlated with leaf dry weight (Table 2). Leaf area was positively (r = 0.33, < 0.001) correlated with leaf fresh weight. The number of leaves per plant was significantly correlated with fresh leaf yield (r = 0.40, < 0.001). Leaf fresh weight was negatively correlated with the weight of pods per plant and the weight of seeds per plant. The number of pods per plant and the weight of seeds per plant were negatively correlated in this study, because some locules and seed sockets in these pods had brownish and poorly developed seeds that were lightweight and shrunken. However, significant and positive correlation was observed between the number of pods per plant and the number of leaves per plant as well as leaf fresh weight (r = 0.51, < 0.0001 and r = 0.18, < 0.001 respectively). The weight of pods per plant was positively and significantly correlated with the seed yield per plant (r = 0.83, < 0.001). Leaf area was negatively correlated with seed yield per plant (r = –0.03) and positively correlated with pod yield per plant (r = 0.69), but in both cases there was no significant correlation.

Discussion

Significant variations in leaf yield and its attributes were observed among the accessions in this study. This variation is attributed to differences between accessions in terms of other leaf yield-related attributes. It is unfortunate that high fresh leaf yield was also significantly associated with low seed yield – well below average.

Significant positive correlation was also observed between fresh leaf yield and dry leaf yield. The five accessions with the highest fresh leaf yield (with the exception of one accession, TOT 4713) had high dry leaf yield as well. The differences observed are likely due to variations in moisture content among the accessions. In terms of leaf area (value per leaf), of the top five accessions in terms of high leaf fresh weight, three accessions (TOT 8532, GKK 25, and TOT 4713) had a leaf area of 74.13, 50.9, and 50.8 cm^2, respectively – well above the average leaf area (44.6 cm^2) of all accessions. This indicates that leaf area is an important trait in the selection of accessions with high leaf yield. Leaf area is affected by plant spacing (Makinde, Oluwole, Ojekale, & Olufeyemi, 2009), and it can also be affected by the frequency of leaf harvesting (Madakadze et al., 2007). TOT 4051 had the smallest leaf area (33.33 cm^2) 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 this study. A high number of leaves has contributed to the high yield in leaf fresh weight of this accession. Thus, not only does leaf area contribute to leaf yield, but the number of leaves does as well. Similarly, the other accessions in the top five had a higher number of leaves, well above the average of all accessions. Fasinmirin and Olufayo (2009) noticed significant differences in the number of leaves in their study of jute mallow, resulting from different soil moisture regimes. Good soil moisture content was associated with high leaf formation.

In terms of weight of pods per plant, the top five accessions in seed yield had a high weight of pods, which corresponds to their seed yield, except for two accessions (MIX and SUD-4) which showed low pod weight and high seed yield. These accessions had low pod weight compared with the other three, but their seed yield was reasonably high. This indicates that the pods from these accessions had a high number of seeds and less biomass compared with the other three accessions. This is similar to the observation of Madakadze et al. (2007) in jute mallow, where a significant increase in seed yield was found to be associated with a decreased number of pods per

Table 2. Correlation coefficient matrix of leaf yield- and seed yield-related traits.

	Leaf fresh weight/ plant	Leaf dry weight per/ plant	Weight of pods/ plant	Weight seeds/ plant	Leaf area	Number of leaves/ plant	Number of pods/ plant
Leaf fresh weight/ plant							
Leaf dry weight/ plant	0.84**						
Weight of pods/ plant	−0.16**	-0.07^{ns}					
Weight seeds/ plant	−0.22***	−0.15*	0.83**				
Leaf area	0.33***	0.30***	0.69^{ns}	-0.03^{ns}			
Number of leaves/ plant	0.40***	0.33***	−0.21***	−0.19**	0.21**		
Number of pods/ plant	0.18**	0.18**	−0.25***	−0.27***	−0.28***	0.51***	

* = significant at $P < 0.05$, ** = significant at $P < 0.01$, *** = significant at $P < 0.001$, ns = non-significant.

plant. The highest seed yield in this study (35.5 g/plant) is equivalent to 2.9t/ha. A seed yield of 2.78t/ha was attained by Madakadze et al. (2007) as the highest in their study, using a spacing of 0.5 × 0.1 m. These authors found that variation in seed yield is dependent on cultivar and cultural management. Other accessions had very low leaf yield. This may be attributed to poor adaptation of the accessions to the cultivation environment, as this is known to affect seed production adversely (Hartmann & Kester, 1963). In our study, the main variation resulted from the differences in accessions; plant spacing was maintained at 0.6 × 0.25 m.

The strong correlation between leaf yield per plant and dry weight per plant suggests that the higher the fresh weight, the higher the leaf dry weight, although there is some slight variation in leaf moisture content among the accessions. Moisture content varied from one accession to another, indicating that leaf dry weight will be affected by the inherent moisture content of the accession in question, as compared with another accession with the same leaf fresh weight but with different moisture content. Leaf area was positively correlated with leaf fresh weight, indicating that leaf area is an important yield component and should be considered during the selection of promising accessions. Leaf surface area contributes to the quantity of food synthesised by the plant during photosynthesis (Kisua, Mwikamba, Makobe, & Muigai, 2015). Accessions with high numbers of leaves are likely to have higher photosynthetic ability that can contribute to the growth and development of the plant. Leaf fresh weight was negatively correlated with the weight of pods per plant and weight of seeds per plant; this shows that it is important to strike a balance between seed yield and leaf yield for economic production of this vegetable. The number of leaves per plant is negatively and significantly correlated with both weight of pods per plant and seed yield per plant. These findings are similar to the results of Mills and Jones (1979) with bell peppers, that showed low pod yield as a result of excessive N treatment, which stimulated more vegetative growth and reduced flowering. Contrary to our results, Madisa, Mathowa, Mpofu, Ndapo, and Machacha (2013) reported that a high number of leaves per plant was correlated with higher pod weight in *C. olitorius*. However, a strong and positive correlation was observed between the number of leaves per plant and the number of pods per plant. For crops grown for their leaves, good vegetative growth before flowering and seed set results in high seed yield (Grubben, 1977; Tindall, 1965; Van Epenhuijsen, 1974). This corroborates what Johnson and Decoteau (1996) reported on jalapeño pepper: they found plant biomass and pod productions to be highly correlated. These results do not match with those of our study because, despite finding a positive correlation between the number of leaves per plant and number of pods per plant, as did Madisa et al. (2013), pods in our study had locules and seed sockets with brownish and poorly developed seeds.

Normally, high numbers and high weight of pods could contribute to the amount of seeds produced by a particular accession, while large leaf area and high numbers of leaves can contribute significantly to leaf yield. Generally, the strong correlation observed between leaf yield-related traits, such as leaf area and numbers of leaves, and seed yield-related traits, such as the weight of pods per plant, indicates the importance of these agronomic traits in the selection of good accessions with promising vegetative and seed yield potential.

Conclusion

The variation in leaf yield of these accessions resulting from their genotypic differences was significant, indicating the potential for useful selection out of this germplasm for accessions with good agronomic traits. The strong and positive correlations between leaf yield-related traits indicate the importance of focusing on more than one agronomic trait during the selection process. Seed yield also varied significantly among the accessions. In considering both seed yield and leaf yield as important agronomic traits for the selection of promising accessions, the challenge becomes how to balance leaf yield and seed yield as these were observed to be inversely related, i.e. accessions with high leaf yield had relatively low seed yield. Nevertheless, the yield of leaves, which are the harvestable part, remains more important than seed yield. Seed yield could be optimised through breeding. More studies are recommended to evaluate how seed yield can be affected by leaf harvesting, and how seed yield can be increased in case we aim to produce seeds.

Acknowledgements

Seed samples of germplasm accessions and experimental site for this study were kindly provided by the World Vegetable Centre, Eastern and Southern Africa.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Nelson Mandela African Institution of Science and Technology, Government of Tanzania.

References

Adediran, O.A., Ibrahim, H., Tolorunse, K.D., & Gana, U.I. (2015). Growth, yield and quality of Jute mallow (*Corchorus olitorius* L.) as affected by different nutrient sources. *International Journal of Agriculture research*, *3*, 3–6.

Aluko, O.A., Olanipekun, T.O., Olasoji, J.O., Abiola, I.O., Adeniyan, O.N., Olanipekun, S.O., … Douglas, A.I. (2014). Effects of organic and Inorganic fertilizer on the yield and nutrient composition of Jute mallow. Global Journal of Agricultural research, 2, 1–7.

Benor, S., Blattner, F.R., Demissew, S., & Hammer, K. (2010). Collection and ethnobotanical investigation of *Corchorus* species in Ethiopia: Potential leafy vegetables for dry regions. *Genetic Resources and Crop Evolution*, 57, 293–306. doi:10.1007/s10722-009-9470-y

Dansi, A., Adjatin, A., Adoukonou-Sagbadja, H., Faladé, V., Yedomonhan, H., Odou, D., & Dossou, B. (2008). Traditional leafy vegetables and their use in the Benin Republic. *Genetic Resources and Crop Evolution*, 55, 1239–1256. doi:10.1007/s10722-008-9324-z

Fasinmirin, J.T., & Olufayo, A.A. (2009). Yield and water use efficiency of jute mallow *Corchorus olitorius* under varying soil water management strategies. *Journal of Medicinal Plants Research*, *3*, 186–191.

Freiberger, C.E., Vanderjagt, D.J., Pastuszyn, A., Glew, R.S., Mounkaila, G., Millson, M., & Glew, R.H. (1998). Nutrient content of the edible leaves of seven wild plants from Niger. *Plant Foods for Human Nutrition (Dordrecht, Netherlands)*, 53, 57–69. doi:10.1023/A:1008080508028

Grubben, G., & Denton, O. (2004). *Plant resources of tropical Africa 2. Vegetables*. Wageningen: PROTA Foundation.

Grubben, G.J.H. (1977). Tropical vegetable and their genetic resources (197 p.). Rome: IBPGR.

Hartmann, H.T., & Kester, D.E. (1963). Plant propagation: Principles and practice. *Soil Science*, 95, 89. doi:10.1097/00010694-196301000-00014

Johnson, C.D., & Decoteau, D.R. (1996). Nitrogen and potassium fertility affects jalapeño pepper plant growth, pod yield and pungency. *HortScience*, 31, 1119–1123.

K'opondo, F., Muasya, R., & Ok, K.A. (Eds.). (2005). A review on the seed production and handling of indigenous vegetables (spiderplant, jute mallow and african nightshade complex). In *Proceedings of the third Horticulture Workshop on Sustainable Horticultural production in the Tropics* (pp. 42–48). Maseno: Maseno University.

Kinabo, J., Mnkeni, A.P., Nyaruhucha, C.N.M., Msuya, J., Haug, A., & Ishengoma, J. (2006). Feeding frequency and nutrient content of foods commonly consumed in the Iringa and Morogoro regions in Tanzania. *International Journal of Food Sciences and Nutrition*, *57*, 9–17. doi:10.1080/09637480500252529

Kisua, J., Mwikamba, K., Makobe, M., & Muigai, A. (2015). Genetic diversity of sweet and grain sorghum populations using phenotypic markers. *International Journal of Biosciences*, 6, 34–46. doi:10.12692/ijb/6.9.34-46

Lewu, F.B., & Mavengahama, S. (2010). Wild vegetables in northern Kwazulu Natal, South Africa: Current status of production and research needs. *Scientific Research and Essays*, *5*, 3044–3048.

Madakadze, R.M., Kodzanayi, T., & Mugumwa, R. (2007). Effect of plant spacing and harvesting frequency on Corchorus olitorious leaf and Seed yields. In K.Z. Ahmed (Ed.), *African crop science proceedings* (Vol. 8, pp. 279–282). El-Minia: African Crop Science Society.

Madisa, M.E., Mathowa, T., Mpofu, C., Ndapo, S., & Machacha, S. (2013). Effect of chicken manure and commercial fertilizer on performance of jute mallow (*Corchorus olitorius*). *Agriculture and Biology journal of North America*, 4, 617–622.

Makinde, S., Oluwole, O., Ojekale, B., & Olufeyemi, S. (2009). Effects of intrapopulation competition on morphological and agronomic characters of Jute plant (*Corchorus olitrius* L.). *African Journal of Biotechnology*, 8, 2195–2201.

Mills, H.A., & Jones, J.B. Jr. (1979). Nutrient deficiencies and toxicities in plants: Nitrogen. Journal Plant Nutritional, 1, 101–122. doi:10.1080/01904167909362704

Mnzava, N.A. (1997). Vegetable crop diversification and the place of traditional species in the tropics. In L. Guarino (Ed.), *Promoting the conservation and use of underutilized and neglected crops (IPGRI)*. Rome: International Plant Genetic Resources Institute.

Odhav, B., Beekrum, S., Akula, U., & Baijnath, H. (2007). Preliminary assessment of nutritional value of traditional leafy vegetables in KwaZulu-Natal, South Africa. *Journal of Food Composition and Analysis*, 20, 430–435. doi:10.1016/j.jfca.2006.04.015

Olaniyi, J.O., & Ajibola, A.T. (2008). Growth and yield performance of *Corchorus olitorius* varieties as affected by nitrogen and phosphorus fertilizers application. *American-Eurasian Journal of Sustainable Agriculture*, 2, 235–241.

Opabode, J.T., & Adebooye, O.C. (2005). Application of biotechnology for the improvement of Nigerian indigenous leaf vegetables. *Afrrican Journal of Biotechnology*, 4, 138–142.

Peksen, E. (2007). Non-destructive leaf area estimation model for faba bean (*Vicia faba* L.). Scientia Horticulturae, 113, 322–328. doi:10.1016/j.scienta.2007.04.003

Tindall, H.D. (1965). Fruits and vegetables in west Africa (259 p.). Rome: FAO.

Van Epenhuijsen, C.W. (1974). Growing native vegetables in Nigeria (113 p.). Rome: FAO.

Velempini, P., Riddoch, I., & Batisani, N. (2003). Seed treatments for enhancing germination of wild Okra (*Corchorus olitorius*). *Experimental Agriculture*, 39, 441–447. doi:10.1017/S0014479703001388

Willem, J.V.R., Ineke, V.H.J., Van Zijl, J.J.B., & Sonja, V.L. (2007). Conservation of African leafy vegetables in South Africa. *African Journal of Food Agriculture Nutrition and Development*, 7, 317–326.