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PHENOTYPIC VARIATION AND SIMULTANEOUS SELECTION OF NUMBER OF LEAVES/PLANT AND SEED MASS IN JUTE MALLOW (*CORCHORUS OLITORIUS*)

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Abstract: *Corchorus olitorius* is a leafy vegetable cultivated for the mucilage in its leaves. Leaf greenness, leaf number, leaf length, and leaf width are popular market traits for this vegetable. Little is known about the direct and indirect contribution of traits to leaf number and seed yield. Forty-two accessions were evaluated in a randomized complete block design with four replications during the 2017 and 2018 cropping seasons. The findings showed that accessions 25, 19, and 28 performed best for leaf length, accessions 31, 22, and 23 for the number of leaves/plant, accessions 4, 18, and 27 for the number of seeds/capsule and accessions 8, 11, and 7 for seed mass. The seed mass was positively related to leaf length, leaf width, and plant height at maturity, the number of seeds/capsule, the number of seeds/capsule and 100-seed mass. The number of leaves/plant was influenced by leaf length, leaf width, and branch length. The path analysis for seed mass showed that the number of branches/plant, seed mass/capsule, the number of seeds/capsule and capsule mass made a large contribution to seed yield. The indirect contribution of traits to the number of leaves/plant was small compared to the direct effect. The leaf length had the largest direct effect on the number of leaves/plant with its largest indirect effect by reducing seed mass. The direct contribution of leaf length to the number of leaves/plant was masked by the phenotypic expression of petal width. The number of branches/plant is a reliable index of seed yield improvement. Hybridization among the best-performing accessions for leaf number, leaf chlorophyll and seed yield will produce new varieties through selection.

Key words: jute mallow, phenotypic variation, character correlation, selection index, yield improvement.

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Introduction

Corchorus olitorius [L.] (jute mallow) is a shrub species in the family Malvaceae. Its origin is traced back to Africa, Asia and the Indo-Burmes region (Anonymous, 2008). Jute mallow is an underutilized leaf vegetable in sub-Saharan Africa. It is a warm-weather crop with a C_4 cycle of photosynthesis. A temperature between 25 and 32°C, rainfall of 600 to 2000 mm annually, and a day length of 12.5 hours produced a high fresh and dry leaf mass at culling (Grubben and Denton, 2004). Jute mallow is grown primarily in Africa, the Middle East, and Asia for its fresh leaves, and to a lesser extent for the fibers in the stem. The vegetable serves as an alternative food source for people in rural and urban areas. The leaves are rich in protein, thiamine, riboflavin, niacin, folate, and dietary fiber, beta-carotene, iron, calcium, and vitamin C (Grubben and Denton, 2004; Lewu and Mavengahama, 2010). The mucilage in the fresh or dried leaves (Whitlock et al., 2003; Ghosh et al., 2017; Ngomuo et al., 2017) enhances the mastication of starchy foods made from cassava flour, pounded boiled cassava and cassava granules, yam flour, maize, sorghum, and rice flour (Benor et al., 2012). Jute mallow is cultivated under a short harvest cycle. The young shoots are culled by uprooting 4 to 5 weeks after sowing. The number of leaves, leaf size, color and taste are market traits. The growers broadcast the seeds on the beds, which increases the demand for seeds. Farmers have consistently provided seeds for sowing. The inadequate supply of quality seeds due to the short cycle of culling is a major setback for sustainable production (Opabode and Adebooye, 2005).

The foliage yield of jute mallow is low, and there are only a few varieties with high leaf and seed yields. This is due to inadequate knowledge of the variability and interdependence of leaf and seed yield and the influence of the environment, which is important for the selection and development of high-yielding varieties. To enhance sustainable production, research needs to focus on the differences between accessions, the direct and indirect contribution of traits to the number of leaves per plant at culling, and high seed yield at maturity. This will ensure simultaneous improvement and increase the efficiency of selection. The correlation coefficient measures the mutual association between the traits. Path coefficient analysis is used to determine the relative contribution of independent traits directly to a dependent trait, and indirectly through other traits to increase selection efficiency. Crop growth and seed development patterns are controlled by genetic and environmental factors. The ability of a vegetable to provide leaves and seeds in different environments is a function of the response of traits to environmental attributes. There is limited information on the direct and indirect contribution of traits to the number of leaves/plant and seed mass, which is important for the selection and development of new varieties. The objectives of this study were 1) to estimate the extent of variation among the jute mallow accessions for agronomic and leaf yield-related traits, 2) to determine the association between traits, and 3) to evaluate the extent of direct and indirect contribution of traits to the number of leaves/plant and seed mass.

Material and Methods

Sources of the accessions and experimental design

Forty-two accessions (Table 1) of jute mallow were evaluated at the Teaching and Research Farm, Federal University Oye Ekiti, Ikole Campus (longitude 7°47′N and latitude 5°31′E, and 555 m above sea level) between August and December in 2017 and 2018. The research location has a bimodal rainfall pattern, i.e., the first rainfall season starts from April to July and from October to November.

Table 1. Forty-two accessions of jute mallow evaluated in Nigeria during 2017 and 2018.

Accession code	Source	Accessions code	Source
Acc 1	NaCGRAB[a]	Acc 23	FUOYE
Acc 2	NaCGRAB	Acc 25	FUOYE
Acc 3	NaCGRAB	Acc 26	FUOYE
Acc 4	NaCGRAB	Acc 27	FUOYE
Acc 5	NaCGRAB	Acc 28	FUOYE
Acc 6	NaCGRAB	Acc 29	FUOYE
Acc 7	NaCGRAB	Acc 30	FUOYE
Acc 8	NaCGRAB	Acc 31	FUOYE
Acc 9	FUOYE[b]	Acc 32	FUOYE
Acc 10	FUOYE	Acc 33	FUOYE
Acc 11	FUOYE	Acc 34	FUOYE
Acc 12	FUOYE	Acc 35	FUOYE
Acc 13	FUOYE	Acc 36	FUOYE
Acc 14	FUOYE	Acc 37	FUOYE
Acc 15	FUOYE	Acc 38	FUOYE
Acc 16	FUOYE	Acc 39	FUOYE
Acc 17	FUOYE	Acc 40	FUOYE
Acc 18	NaCGRAB	Acc 41	FUOYE
Acc 19	NaCGRAB	Acc 42	FUOYE
Acc 20	NaCGRAB	Acc 43	FUOYE
Acc 21	NaCGRAB		
Acc 22	NaCGRAB		

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The rainfalls were abundant (700–1000 mm) with an annual temperature of 28°C and high humidity. Derived guinea savannah was the main vegetation. Before soil preparation, the soil of the experimental site had a pH (in H_2O, 1:1) of 5.7, OM content (%) of 0.82, N (%) content of 0.08, available phosphorus (Bray method) of 219.33, exchangeable Mg content (C mol kg^{-1}) of 0.19, exchangeable K content (C molkg^{-1}) of 0.48, exchangeable Na content (C mol kg^{-1}) of 0.07, exchangeable Ca content (C mol kg^{-1}) of 2.93, ECEC of 3.68, and Zn (C mol kg^{-1}) of 1.12, copper (Cu) (C mol kg^{-1}) of 1.01, Mn (C mol kg^{-1}) of 107.7, Fe (C mol kg^{-1}) of 180.07, the sand content of 68%, the silt content of 20%, the clay content of 11%, and the textural class – sandy loam.

Before sowing, seed dormancy was broken by hot and cold water treatment. The air-dried seeds were sown in multi-pot seedling trays, each tray holding 60 seedlings. Water was applied to the trays using a hand sprayer. The seedling trays were covered with a black nylon sheet and placed in a germination room at 22°C for 72 hours. The trays were then returned to the nursery shed, and the developing seedlings were watered once or twice a day for up to 4 weeks. One week before transplanting, 1 g of urea was dissolved in 1 l of water and applied to the seedlings using a hand sprayer. The field trial was conducted according to a randomized complete block design with four replications. Each plot was planted in two rows with a length of 7 m and a distance of 1 m between the rows. At 4 weeks old, vigorous seedlings were transplanted with the soil ball at a distance of 0.75 m between the plants on the side of the ridges 1 m apart. Two weeks after transplanting, 30 g of a fungicide (Ridomill WP) was dissolved in 20 l of water and the plants were sprayed. Weeds were removed manually using hoes at 6, 8, and 12 weeks after transplanting (WAT). An insecticide, Karate EC (20 ml in 20 liters of water), was sprayed at 5 WAT to reduce insect infestations and insect-borne diseases. A foliar application of organic fertilizer, Super Gro fertilizer (ethoxylated, alkylphenol), and polysiloxane, (manufactured by GNLD International, NAFDAC No. A5-0590) was applied at a rate of 100 ml in 10 liters of water at six and eight WAT. Physiological and reproductive traits were monitored until culling (Table 2) following the descriptor list published for *Corchorus olitorius* (Anonymous, 2008). The leaf chlorophyll content was measured at 5 weeks on 30 randomly sampled leaves in three replications using a chlorophyll meter machine (CCM-200 *PLUS*, Opti-Sciences, United States of America).

Table 2. Traits and descriptions of jute mallow accessions evaluated in Nigeria between 2017 and 2018.

Trait	Description
Days to 50% flowering (d)	Number of days from sowing to the opening in 50% of the plants on each plot.
Number of leaves/plant at flowering	The number of leaves/plant was counted on 10 randomly selected plants per accession at flowering.
Plant height at maturity (m)	Measured from the ground level to the tip of the highest point on 10 plants randomly selected at maturity.
Leaf length at flowering (cm)	Measured with a meter rule at the longest point on 10 leaves randomly selected at 50% flowering.
Leaf width at flowering (cm)	Measured with a meter rule at the widest point on 10 leaves randomly selected at 50% flowering.
Branch length at flowering (cm)	Branch length at 50% flowering was measured with a meter rule from the point of attachment to the plant to the other end.
Leaf chlorophyll	Determined on 10 leaves randomly selected/accession using a chlorophyll meter machine.
Number of branches/plant	Counted on five plants randomly selected per accession at maturity.
Petal length (cm)	Determined on the longest point on 10 petals randomly selected with a meter rule at flowering.
Petal width (cm)	Measured on the widest point on 10 petals randomly selected per accession with a meter rule at flowering.
Sepal length (cm)	Measured at the longest point on 10 sepals randomly selected at flowering with a meter rule.
Sepal width (cm)	Measured at the widest point on 10 sepals randomly selected at flowering with a meter rule.
Stamen height (cm)	Measured at the highest point on 10 stamens randomly selected at flowering.
Pistil height (cm)	Measured at the highest point on five randomly selected pistils at flowering.
Flower size	Small flower size = 1, large flower size = 2
Number of capsules per plant	The average number of capsules per plant on 5 plants randomly harvested at culling.
Capsule length (cm)	The average length of 10 capsules per plant randomly taken from 5 plants at culling.
Capsule mass (g)	Dried capsules harvested from five randomly sampled plants were weighed on a sensitive weighing balance.
Number of loculus/capsule	The average number of loculi/capsule taken from 5 randomly selected capsules/plant.
100-seed mass (g)	Average 100-seed mass measured on a sensitive weighing balance.
Number of seeds per capsule	The average number of seeds/capsule from 10 capsules per plant randomly selected from 5 plants.
Seed mass/capsule (g)	The number of seeds/capsule at culling were air-dried, at constant weight, the average weight of seed (g) from 10 capsules was determined from 5 randomly selected plants.
Seed mass/plant (kg)	The number of harvested seeds/plant were air-dried and weighed on a sensitive weigh balance.

The agronomic traits were averaged over the years and the homogeneity of error variance was tested. The performance of the accessions was tested over years. With insignificant accession × year interaction for most traits, the mean values showed little response to environmental factors. Subsequently, the accession means were used to perform the combined analysis of variance (ANOVA) for 44 accessions over years using the general linear model (PROC-GLM procedure of SAS, 2002) to partition the total variation into components due to genotype (G), year (Y), and G x Y interaction effects. The genotype was treated as a fixed effect and the year as a random effect. The multiple comparisons of the main effect were performed by the Tukey's HSD test. The Pearson's correlation coefficient between traits was determined using PROC CORR (SAS, 2012). The path coefficient analysis described by Wright (1921) and Dewey and Lu (1959) was used to determine the direct and indirect effect of independent traits on leaf number and seed yield (response variables). Other traits with positive correlation coefficients were considered as causal variables.

Results and Discussion

Variation in vegetative, reproductive, and seed yield traits

Significant ($P \leq 0.01$) mean squares were recorded for leaf chlorophyll, leaf length, leaf width, the number of leaves per plant, plant height at flowering, branch length at maturity, the number of branches per plant and plant height at maturity, petal length and width, pistil height, days to 50% flowering, flower size, capsule length, the number of capsules per plant, capsule mass, the number of seeds per capsule, seed mass and 100-seed mass (Table 3). This is consistent with the genetic constitution of the accessions and the influence of the environment. The findings are similar to previous reports by Fasinmirin and Olufayo (2009), Nwangburuka and Denton (2012) and Adebo et al. (2015), who noted differences among jute mallow accessions in terms of leaf morphology, vegetative, reproductive, capsule and seed yield traits. In contrast, low phenotypic variability in leaf length, leaf width, and the number of leaves/plant was found in jute mallow accessions from East Africa (Ngomuo et al., 2017). The year effect significantly ($P \leq 0.01$) influenced leaf width, the number of leaves per plant, plant height at flowering, plant height at maturity, petal length, pistil height, capsule length, and capsule weight, the number of seeds per capsule, and 100-seed mass. Mean squares of the genotype × year interaction were insignificant ($P \geq 0.05$) for all traits except for leaf length, number of leaves/plant, sepal length, stamen height and capsule length. The genotype accounted for a larger proportion of the total variation in all traits compared to the genotype × year interaction and year effects. The metric traits (plant height at flowering, number of seeds/capsule, 100-seed mass and capsule length) were responsive to precipitation, temperature, humidity, and soil factors (year effect). This indicates that the year effect is important in defining phenotypic variability. This trend of observation could change if this evaluation were carried out elsewhere. Insignificant accession by year interaction for the traits implies that the genotypes were irresponsive to environmental factors, suggesting a high predictability of performance (Table 3).

Table 3a. Combined analysis of variance for vegetative traits in jute mallow accessions during 2017 and 2018.

Source of variation	df	Leaf chlorophyll	Leaf length (cm)	Leaf width (cm)	Number of leaves/plant	Plant height at flowering (cm)	Branch length at maturity (cm)	Number of branches	Plant height at maturity (cm)
Genotype	41	95.06**	47.55**	12.28**	4700.20**	208.91*	4520.84**	1238.88**	3475.68**
Rep (year)	5	1.03	3.50	0.76	16.10	165.90*	526.27	49.53	216.39
Genotype × year	83	1.99	1.92	1.83**	63.41**	26.53	483.47	29.77	33.73
Error	165	14.65	2.08	0.46	418.00	89.28	563.83	53.62	243.30
Mean		46.10	9.06	4.44	29.05	50.23	99.38	21.88	135.40

*, **0.05 and 0.01% levels of probability.

Table 3b. Combined analysis of variance for flower metric traits in jute mallow accessions during 2017 and 2018.

Source of variation	Df	Petal length (cm)	Petal width (cm)	Pistil height (cm)	Days to 50% flowering	Flower size	Sepal length	Sepal width	Stamen height
Genotype	41	0.42**	0.06**	0.18**	307.60**	4.34**	0.14**	0.02**	0.19**
Replicate (year)	5	0.01	0.002	0.001	356.11	0.02	0.0001	0.002	0.003
Genotype × year	83	0.04	0.006	0.001	33.73	0.00008	0.002*	0.005	0.01*
Error	165	0.01	0.002	0.001	24.40	0.04	0.009	0.007	0.74

*, **0.05 and 0.01% levels of probability.

Table 3c. Combined analysis of variance for capsule, and seed yield in jute mallow accessions during 2017 and 2018.

Source of variation	df	Number of seeds/capsule	Number of locules/capsule	Seed mass/ capsule (g)	100-seed weight (g)	Number of capsules/plant	Capsule mass (g)	Capsule length (cm)
Genotype	41	6703.70**	1393.90**	0.04**	0.01***	77412.44***	10599.71**	785.5**
Replicate (year)	3	2480.92**	5.30	0.007	0.006**	1078.63	308.51	8.20**
Genotype × year	83	193.51	6.40	0.001	0.003	425.56	463.63	84.86**
Error	165	177.35	12.29	0.004	0.25	4239.87	452.11	84.86

*, **0.05 and 0.01% levels of probability.

The top five accessions for leaf length, leaf width and number of leaves/plant are shown in Figures 1, 2, and 3. Accessions 25, 19, and 28 were pollen sources for leaf length, accessions 20, 27, and 1 for leaf width, accessions 31, 22, and 23 for the number of leaves/plant, and accessions 8, 11, and 7 for branch length. Considering seed metric traits, accessions 4, 18, and 27 outperformed the others for the number of seeds/capsule (Figure 4). A diallel crossing pattern among these accessions may recombine the genes for these traits and produce segregating populations for the high number of leaves/plant and seed mass for selection and variety development. The five accessions with the highest number of branches/plant at culling were accessions 11, 8, 20, 12, and 23, which had 71, 62, 54, 58 and 38 leaves/plant, respectively (Figure 5). The leaf chlorophyll content peaked (54.01) in accession 40, followed by accession 39 (52.75), accession 42 (53.58), accession 27 (53.53) and accession 25 (52.37).

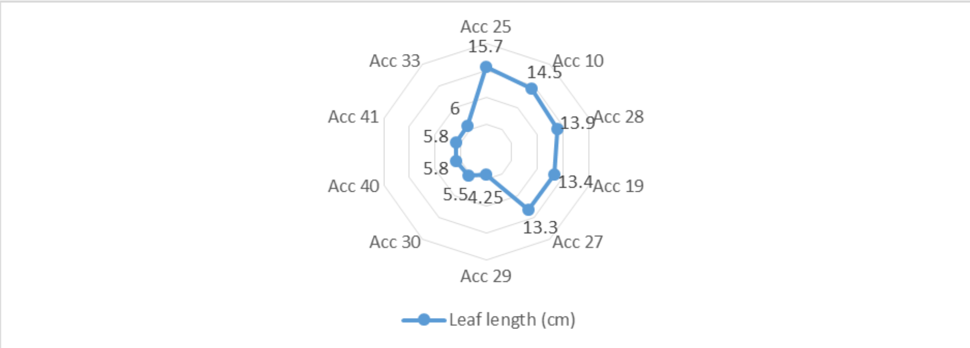

Figure 1. Leaf length (cm) at flowering among top and bottom five accessions of jute mallow during 2017 and 2018.

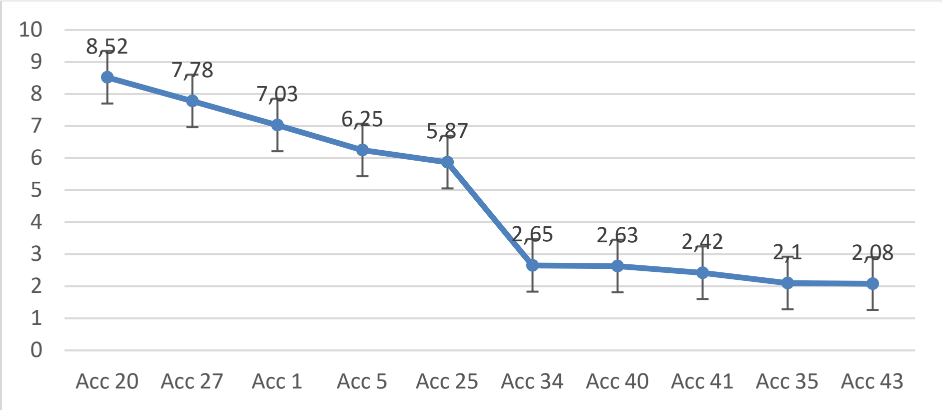

Figure 2. Leaf width (cm) among the top and bottom five accessions of jute mallow at flowering during 2017 and 2018.

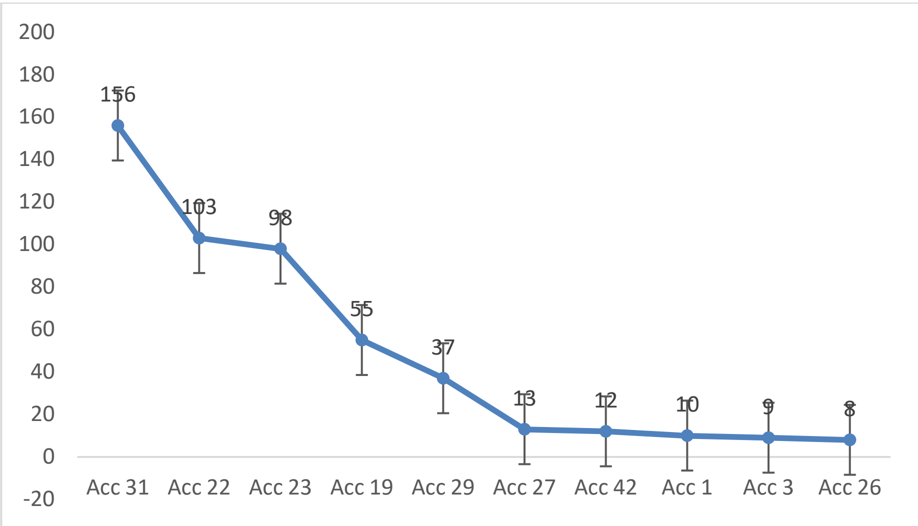

Figure 3. Number of leaves/plant among the top and bottom five accessions at flowering during 2017 and 2018.

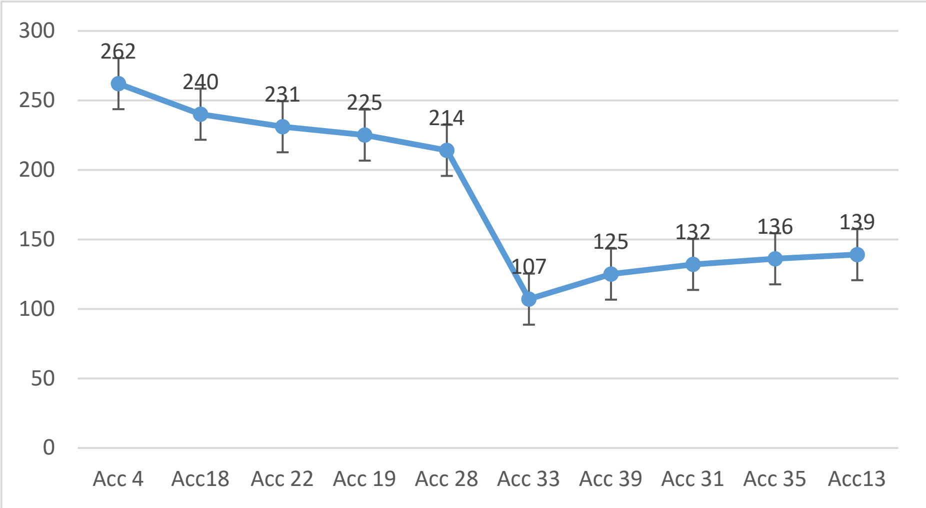

Figure 4. Number of seeds/capsule among top and bottom five accessions of jute mallow during 2017 and 2018.

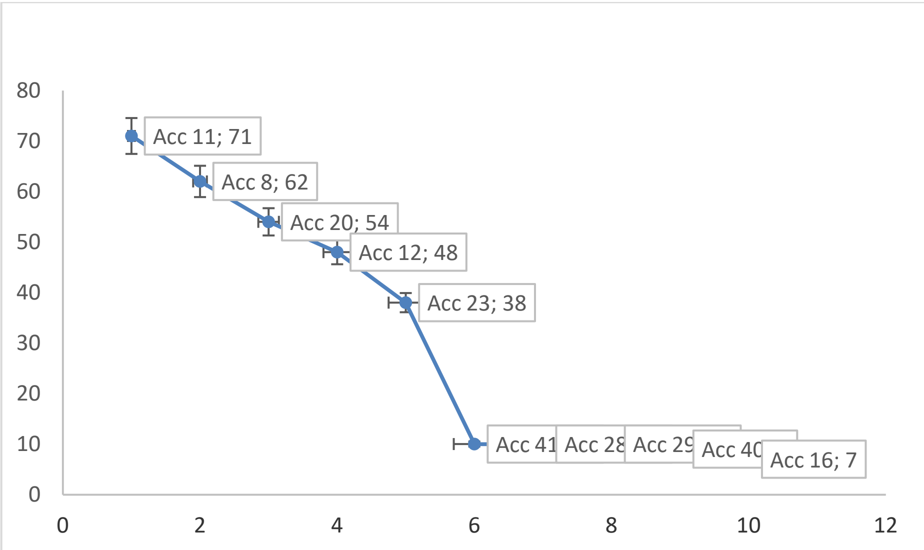

Figure 5. Number of branches/plant at culling among the top and bottom five accessions of jute mallow during 2017 and 2018.

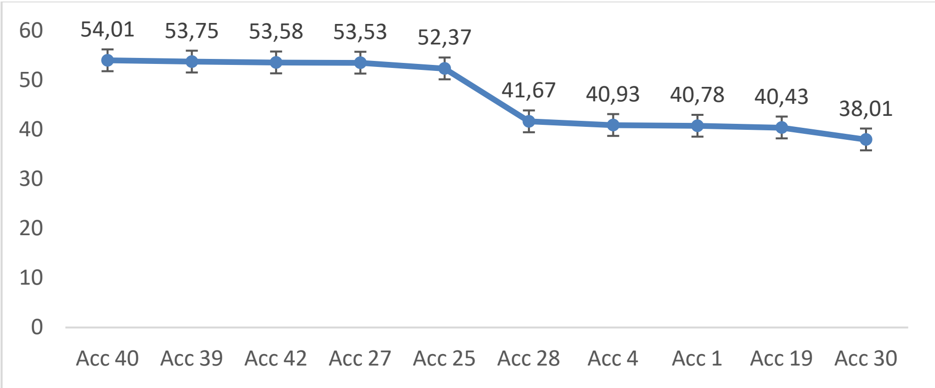

Figure 6. Leaf chlorophyll content among the top and bottom five accessions of jute mallow during 2017 and 2018.

Association between traits

Correlation between traits is important in crop improvement to enhance selection efficiency. Several authors have used the correlation coefficient, which measures the degree of association between traits for selection. The high degree of correlation between traits may be associated with the indirect effect of the third factor (Cruz, 2016). The number of leaves/plant was significantly correlated with leaf length (r=0.26*), leaf width (r= 0.12*), number of branches (r= 0.25*), plant height (r= 0.12*), and branch length (r= 0.25*) (Table 4). A positive association between seed mass and leaf length, leaf width, plant height at flowering and plant height at maturity suggests an efficient translocation of photo-assimilates produced in the leaves to the sink (number of seeds/capsule, number of seeds/capsule, 100-seed mass/capsule). A negative correlation coefficient between the number of leaves per plant and capsule length (r= -0.15*) and the number of capsules/plant (r= -0.13*) is similar to the previous report of Ngomuo et al. (2017) on *C. olitorius.* This suggests that fewer leaves were produced at the reproductive stage than at the vegetative stage. In contrast, Medisa et al. (2013) indicated a positive association between the number of leaves/plant and capsule mass. The leaves of vegetable crops are harvested early and consumed fresh. At post-anthesis stage, the photo-assimilates are channelled to the reproductive structures and sinks (seeds), producing only a few leaves/plant.

The seed mass was negatively correlated with leaf chlorophyll (r=-0.22*) and capsule length (r=-0.59**). An inverse relationship between the number of capsules/plant and seed mass showed effects on seed production. This suggests that some loculi within the capsules were seedless. In another study, Madakadze et al. (2007) indicated high seed mass in jute mallow. This was dependent on cultivar and cultivation practices. On the other hand, the seed mass showed a positive correlation coefficient with leaf length (r=0.32*), leaf width (r=0.38*), plant height at flowering (r=0.13*), plant height at maturity (r=0.32*), number of seeds/capsule (r=0.37*), number of seeds/capsule (r=0.72**) and 100-seed mass/capsule (r=0.19*). The number of capsules/plant had a positive and significant correlation coefficient with leaf width (r=0.12*). The number of leaves/plant and leaf size (leaf length and width) are market traits for leafy vegetables. A significantly negative correlation coefficient between seed mass and capsule length suggests that capsule length is not an index of seed mass improvement. Moreover, the seed mass is the sink, while the capsule is an intermediate sink for photosynthates produced in the leaves. Accessions of jute mallow with a long capsule length may have few seeds per capsule. In another study, Panchbhaiya et al. (2017) found a negative correlation coefficient between seed yield and capsule length in common bean.

Contribution of agronomic traits to the number of leaves/plant and seed yield

The values for the indirect effect of the traits on the number of leaves/plant were generally low in magnitude compared to the direct effect (Table 5). The leaf length had the largest direct effect on the number of leaves/plant with its largest indirect effect through the reduction of seed mass. The leaf length showed a significantly positive correlation coefficient with seed mass (Table 4). A high direct effect for leaf length is consistent with the previous report of Tejaswini et al. (2017). Therefore, leaf length is a reliable index to improve the number of leaves/plant. The number of leaves/plant and seed yield are complex traits that are highly dependent on several other traits. The direct contribution of leaf width to the number of leaves was masked by other traits such as leaf chlorophyll, petal width, sepal length, flower size, branch length, and the number of capsules/plant. This justifies the competition for photo-assimilates between vegetative and reproductive traits. The leaf width and plant height at flowering indirectly enhanced the leaves produced on each plant. This may be associated with a positive and significant association between the number of leaves/plant, leaf length, and leaf width. In the crop improvement program, selection in favor of leaf length and leaf width will complement the number of leaves/plant. Considering traits with a negligible, low, and moderate negative direct effect on the number of leaves, selection of these traits may be ineffective in improving the number of leaves. The complementarity between leaf length and width for high leaf number is similar to the previous report of Nwangburuka and Denton (2012). Capsule length and seed mass masked the phenotypic expression of leaf number. A negative correlation coefficient between pistil height and the number of leaves/plant (r=-0.13*) suggests the limitation of selection of traits based on inter-trait association alone. The seed mass, 100-seed mass, and seed mass/capsule showed a high indirect contribution to the number of leaves/plant. The sepal length had the largest negative direct effect on the number of leaves/plant at flowering and the largest negative indirect effect through a reduction in petal length. The residual factor (R^2=0.42) indicates that 68% of the total variation in the number of leaves/plant was explained by agronomic traits. A large contribution of branch length to the number of leaves/plant at flowering was masked by petal length and width, leaf width, plant height at flowering, and 100-seed mass. This demonstrates the importance of leaf length, pistil height, and leaf width as indices for improving the number of leaves/plant.

Table 4. Correlation coefficients between vegetative and seed yield traits.

Leaf chlorophyll	Leaf chlorophyll	Leaf length	Leaf width	Plant height at flowering	Plant height at flowering	Capsule mass	Capsule length	Days to 50% flowering	Number of locules	Number of seeds/ capsule	Seed mass
Leaf length	0.04										
Leaf width	-0.13*	0.48**									
Number of leaves/ plant	-0.007	0.26*	0.12*								
Plant height at flowering	0.008	0.30**	0.26*	0.07							
Capsule mass	-0.13*	-0.002	0.06	0.05	-0.11						
Capsule length	0.35**	-0.30**	-0.59**	-0.15*	-0.25*	-0.14*					
Days to 50% flowering	-0.38**	0.28*	0.50**	0.05	0.13*	0.09	-0.61**				
Number of locules/ capsule	-0.23**	0.22*	0.31**	-0.10	-0.002	0.07	-0.41**	0.59**			
Number of seeds/capsule	-0.32**	0.30**	0.55**	0.05	0.19*	0.19*	-0.78**	0.78**	0.58**		
Seed mass	-0.20*	0.32**	0.38**	-0.04	0.13*	-0.06	-0.31**	0.60**	0.37**	0.48**	
100-seed mass	-0.13*	0.2	0.27*	-0.02	0.07	0.01	-0.42**	0.44**	0.27*	0.4	0.19*
Petal length	0.01	0.26*	0.19*	-0.18*	0.29*	-0.11*	-0.32**	0.13*	0.12*	0.28**	0.19*
Petal width	0.09	-0.14	-0.06	-0.20*	-0.04	-0.24*	0.07	-0.16*	-0.03	-0.1	-0.02
Sepal length	0.18*	0.04	-0.008	-0.47**	0.06	-0.07	0.14*	-0.16*	0.009	-0.14*	0.006
Sepal width	0.05	0.0002	-0.05	-0.09	-0.01	-0.07	0.003	0.02	0.03	0.01	0.08
Stamen height	0.006	0.28*	0.33**	-0.11	0.17*	-0.05	-0.47**	0.28*	0.33**	0.46**	0.22*
Pistil height	-0.04	0.24	0.36**	-0.12*	0.2	0.02	-0.54**	0.34**	0.30**	0.52**	0.23*
Flower size	-0.09	-0.08	-0.01	-0.24*	-0.09	-0.06	-0.21*	0.08	0.14*	0.16*	0.06
Plant height at maturity	-0.09	0.02	0.03	0.12*	0.32**	-0.04	-0.11*	0.003	0.002	0.07	0.01
Number of branches/ plant	-0.09	0.005	0.26*	0.08	0.29	-0.06	-0.38**	0.39**	0.21*	0.38**	0.08
Branch length	-0.09	0.007	-0.11	0.25*	-0.15*	0.03	-0.08	0.013*	-0.13*	0.03	0.08
Number of capsules/ plant	-0.09	0.05	0.12*	-0.13*	-0.002	-0.13*	-0.19*	0.15	0.09	0.25*	0.007

Continuation Table 4. Correlation coefficients between vegetative and seed yield traits.

Leaf chlorophyll	100-seed mass	Petal length	Petal width	Sepal length	Stamen height	Pistil height	Flower size	Plant height at maturity	Number of branches/ plant	Branch length	Number of capsules/ plant
Leaf length											
Leaf width											
Number of leaves/ plant											
Plant height at flowering											
Capsule mass											
Capsule length											
Days to 50% flowering											
Number of locules/ capsule											
Number of seeds/capsule											
Seed mass											
100-seed mass											
Petal length	0.11										
Petal width	-0.20*	0.53**									
Sepal length	-0.08	0.46**	0.35**								
Sepal width	0.02	0.17*	0.12*	0.07							
Stamen height	0.15*	0.65**	0.40**	0.34**	0.06						
Pistil height	0.26*	0.75**	0.44**	0.38**	0.07	0.79**					
Flower size	0.06	0.62**	0.61**	0.34**	0.1	0.56**	0.70**				
Plant height at maturity	0.07	0.004	-0.01	-0.18*	0.03	-0.02	0.01	-0.06			
Number of branches/ plant	0.17*	-0.007	-0.13*	-0.14*	-0.08	0.08	0.09	-0.13*	0.17		
Branch length	-0.12*	-0.24*	-0.17*	-0.21*	-0.10	-0.01	-0.09	-0.02	0.05	0.06	
Number of capsules/ plant	0.12*	0.15*	-0.003	0.16	0.001	0.12*	0.26*	0.25	-0.02	0.05	0.06

Table 5. Direct and indirect effects of some characters on the number of leaves/plant.

Effect	Leaf length	Leaf width	Leaf chlorophyll	Plant height at flowering	Capsule length	Capsule width	Seed mass	Seed mass/ capsule	100-seed mass
Direct effect	0.33	0.003	0.04	-0.032	-0.183	0.099	-0.217	-0.087	-0.122
Leaf length		0.001	0.002	-0.010	0.055	0.028	-0.056	-0.028	-0.025
Leaf width	0.16		-0.006	-0.008	0.110	0.050	-0.102	-0.034	-0.033
Leaf chlorophyll	0.01	0.000		0.000	-0.064	-0.038	0.048	0.018	0.016
Plant height at flowering	0.10	0.001	0.000		0.047	0.014	-0.033	-0.012	-0.010
Capsule length	-0.09	-0.002	0.015	0.008		-0.061	0.129	0.027	0.052
Capsule width	0.09	0.001	-0.017	-0.004	0.113		-0.145	-0.053	-0.054
Seed mass	0.09	0.001	-0.010	-0.005	0.109	0.066		-0.037	-0.038
Seed mass/capsule	0.11	0.001	-0.009	-0.004	0.057	0.060	-0.092		-0.024
100-seed mass	0.06	0.001	-0.006	-0.003	0.078	0.044	-0.067	-0.017	
Petal length	0.08	0.001	0.001	-0.010	0.060	0.013	-0.052	-0.017	-0.014
Petal width	-0.04	0.000	0.004	0.002	-0.014	-0.016	0.001	0.002	0.024
Sepal length	0.01	0.000	0.008	-0.002	-0.027	-0.016	-0.008	-0.001	0.010
Pistil height	0.08	0.001	-0.002	-0.007	0.100	0.034	-0.094	-0.021	-0.032
Flower size	-0.02	0.000	-0.004	0.003	0.039	0.008	-0.033	-0.006	-0.008
Number of branches/plant	0.002	0.001	-0.007	-0.010	0.069	0.039	-0.104	-0.007	-0.021
Branch length	0.002	0.000	-0.002	0.005	0.016	0.001	-0.004	0.007	0.015
Number of capsules/plant	0.02	0.000	-0.001	0.000	0.035	0.015	-0.055	-0.001	-0.016

Continuation Table 5. Direct and indirect effects of some characters on the number of leaves/plant.

Effect	Petal length	Petal width	Sepal length	Pistil height	Flower size	Number of branches/plant	Branch length	Number of capsules/plant
Direct effect	-0.046	0.056	-0.420	0.245	-0.156	0.065	0.133	-0.063
Leaf length	-0.012	-0.008	-0.017	0.060	0.013	0.000	0.001	-0.003
Leaf width	-0.009	-0.004	0.004	0.089	0.003	0.017	-0.015	-0.008
Leaf chlorophyll	-0.001	0.005	-0.076	-0.011	0.015	-0.011	-0.005	0.001
Plant height at flowering	-0.013	-0.003	-0.029	0.051	0.015	0.019	-0.021	0.000
Capsule length	0.015	0.004	-0.063	-0.134	0.033	-0.025	-0.011	0.012
Capsule width	-0.006	-0.009	0.070	0.084	-0.013	0.026	0.002	-0.010
Seed mass	-0.011	0.000	-0.016	0.106	-0.024	0.031	0.003	-0.016
Seed mass/capsule	-0.009	-0.002	-0.003	0.058	-0.010	0.005	-0.011	0.000
100-seed mass	-0.005	-0.011	0.034	0.064	-0.010	0.011	-0.016	-0.008
Petal length		0.030	-0.195	0.186	-0.098	0.000	-0.033	-0.010
Petal width	-0.025		-0.148	0.110	-0.096	-0.009	-0.023	0.000
Sepal length	-0.021	0.020		0.095	-0.055	-0.009	-0.028	-0.010
Pistil height	-0.035	0.025	-0.163		-0.110	0.006	-0.013	-0.017
Flower size	-0.029	0.035	-0.147	0.173		-0.008	-0.003	-0.016
Number of branches/plant	0.000	-0.008	0.059	0.023	0.020		0.009	-0.004
Branch length	0.011	-0.010	0.089	-0.024	0.003	0.004		-0.004
Number of capsules/plant	-0.007	0.000	-0.068	0.065	-0.039	0.004	0.009	

The number of branches/plant, seed mass/capsule, the number of seeds/capsule, and capsule mass showed a large positive direct effect on seed yield (Table 6). This was reduced by a high and negative direct effect of the number of leaves/plant, capsule length, and flower size. This implies that the number of branches/plant is a reliable index for seed yield improvement (Table 6). This is related to a positive association between branch length and seed mass.

Table 6. Path coefficient analysis depicting the direct and indirect effects of some traits on seed mass.

Effect	Number of branches/ plant	Seed mass/ capsule	Number of seeds/ capsule	Capsule mass	Number of leaves/plant	Plant height at flowering	Capsule length	100-seed mass	Petal length
Direct effect	0.26	0.22	0.19	0.17	-0.12	-0.05	-0.10	-0.005	-0.035
Number of branches/plant		0.086	0.042	0.066	-0.010	-0.013	0.039	-0.001	0.000
Seed mass/capsule	0.101		0.112	0.130	-0.007	-0.009	0.080	-0.002	-0.010
Number of seeds/capsule	0.058	0.131		0.098	0.012	0.000	0.042	-0.001	-0.004
Capsule mass	0.105	0.175	0.114		-0.006	-0.006	0.063	-0.002	-0.005
Number of leaves/plant	0.022	0.013	-0.020	0.009		-0.003	0.016	0.000	0.006
Plant height at flowering	0.078	0.044	0.0001	0.023	-0.009		0.026	0.000	-0.010
Capsule length	-0.100	-0.176	-0.080	-0.103	0.019	0.011		0.002	0.011
100-seed mass	0.046	0.090	0.053	0.074	0.003	-0.004	0.043		-0.004
Petal length	-0.002	0.064	0.024	0.022	0.022	-0.013	0.033	-0.001	
Petal width	-0.036	-0.022	-0.007	-0.027	0.024	0.002	-0.008	0.001	-0.019
Sepal length	-0.037	-0.032	0.002	-0.028	0.057	-0.003	-0.015	0.000	-0.016
Sepal width	-0.021	0.004	0.006	0.005	0.012	0.001	0.000	0.000	-0.006
Stamen length	0.022	0.103	0.064	0.047	0.014	-0.008	0.049	-0.001	-0.023
Pistil length	0.025	0.117	0.058	0.057	0.015	-0.009	0.056	-0.001	-0.026
Flower size	-0.034	0.038	0.029	0.014	0.030	0.004	0.022	0.000	-0.022
Plant height at maturity	0.046	0.016	0.0009	0.001	-0.014	-0.015	0.011	0.000	0.000
Branch length	0.017	0.007	-0.025	0.002	-0.031	0.007	0.009	0.001	0.009
Number of capsules/plant	0.015	0.058	0.019	0.026	0.017	0.000	0.020	-0.001	-0.006

Therefore, a phenotypic improvement in branch length will complement seed mass. The plant height at flowering and maturity enhanced branch length, and these traits were positively associated. Accessions with a high number of branches/plant showed a moderately high seed mass/plant. The direct and positive contribution of the number of seeds/capsule to seed mass was masked by the negative indirect effect of capsule length, petal width and branch length. Plant height both at flowering and maturity showed little influence on the number of seeds/capsule. A phenotypic selection directed toward the number of branches/plant will compensate for more flowers per plant, and consequently, high seed mass/plant. However, the direct effect of the number of branches/plant had the largest negative indirect effect through capsule length, sepal length, petal width and flower size. The number of branches/plant had a significantly negative correlation coefficient (r=0.38**) with capsule mass. The direct path from the number of branches/plant to seed mass was masked by reproductive structures (capsule length, flower size, sepal length, and sepal width). This may be related to the demand for photo-assimilates by these reproductive organs. The direct path of seed mass was reduced by the negative indirect effect of the number of leaves/plant at flowering.

Continuation Table 6. Path coefficient analysis depicting the direct and indirect effects of some traits on seed mass.

Effect	Petal width	Sepal length	Sepal width	Stamen length	Pistil length	Flower size	Plant height at maturity	Branch length	Number of capsules/plant
Direct effect	0.119	0.063	-0.007	0.110	-0.034	-0.078	0.024	0.053	0.110
Number of branches/plant	-0.016	-0.009	0.001	0.009	-0.003	0.010	0.004	0.003	0.006
Seed mass/capsule	-0.012	-0.009	0.000	0.051	-0.018	-0.013	0.002	0.002	0.028
Number of seeds/capsule	-0.004	0.001	0.000	0.037	-0.010	-0.012	0.000	-0.007	0.011
Capsule mass	-0.019	-0.011	0.000	0.031	-0.012	-0.007	0.000	0.001	0.017
Number of leaves/plant	-0.024	-0.030	0.001	-0.013	0.004	0.019	0.003	0.014	-0.015
Plant height at flowering	-0.006	0.004	0.000	0.019	-0.007	0.007	0.008	-0.008	0.000
Capsule length	0.009	0.009	0.000	-0.053	0.019	0.017	-0.003	-0.004	-0.021
100-seed mass	-0.024	-0.005	0.000	0.017	-0.009	-0.005	0.002	-0.006	0.014
Petal length	0.064	0.029	-0.001	0.072	-0.026	-0.049	0.000	-0.013	0.017
Petal width		0.022	-0.001	0.045	-0.015	-0.048	0.000	-0.009	0.000
Sepal length	0.042		-0.001	0.038	-0.013	-0.027	-0.005	-0.011	0.018
Sepal width	0.015	0.005		0.007	-0.003	-0.008	0.001	-0.005	0.000
Stamen length	0.048	0.022	0.000		-0.027	-0.044	-0.001	-0.001	0.014
Pistil length	0.053	0.025	-0.001	0.087		-0.055	0.000	-0.005	0.029
Flower size	0.073	0.022	-0.001	0.062	-0.024		-0.001	-0.001	0.028
Plant height at maturity	-0.002	-0.012	0.000	-0.003	0.000	0.005		0.003	-0.002
Branch length	-0.021	-0.013	0.001	-0.002	0.003	0.002	0.001		0.007
Number of capsules/plant	0.000	0.010	0.000	0.014	-0.009	-0.020	0.000	0.004	

The inverse relationship between capsule length and seed mass is consistent with the masking action of capsule length on the direct path to seed yield. The sepal length masked the phenotypic expression of the number of leaves/plant, and this was further enhanced by a negative indirect effect on petal length. This is consistent with the negative association between these traits. The number of leaves/plant showed a moderate and negative direct effect on seed mass. This may be ascribed to low to moderate leaves retained by the plant at seed maturity. The direct effect of the number of branches/plant on seed mass was evident in the mean performance for seed mass and branch length, with accessions 11 and 8 performing best for both traits. Similarly, accessions 22 and 19 performed best for leaf length and number of leaves/plant. This indicates complementarity between both traits for the number of leaves. The residual (42 %) indicates that 68 % of the total variation in seed mass (dependent variable) was explained by other traits.

Conclusion

The study showed significant differences among the accessions of jute mallow in terms of agronomic, capsule, and seed yield traits. Promising accessions for leaf number/plant (accession 31), leaf length (accession 25), leaf width (accession 20), number of seeds/capsule (accession 4), and leaf chlorophyll (accession 40) are potential pollen parents for hybridization to develop a segregating population providing high leaf number, leaf chlorophyll and seed yield for selection. Phenotypic improvement in leaf length will enhance the number of leaves per plant. Direct selection of the number of branches/plant, the number of seeds/capsule, and the seed mass will improve seed yield. Accession 31 with five times the mean for the number of leaves/plant, and accession 22 with three times the mean for the number of leaves/plant are recommended for further genetic improvement.

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FENOTIPSKA VARIJACIJA I SIMULTANA SELEKCIJA BROJA LISTOVA/BILJCI I MASE SEMENA KOD JUTENOG SLEZA (*CORCHORUS OLITORIUS*)

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R e z i m e

Corchorus olitorius je lisnato povrće koje se uzgaja zbog sluzi u listovima. Zelenilo listova, broj listova, dužina lista i širina lista su popularne karakteristike na tržištu ovog povrća. Malo se zna o direktnom i indirektnom doprinosu karakteristika kao što su broj listova i prinos semena. Procenjena su četrdeset i dva genotipa u randomizovanom kompletnom blok dizajnu sa četiri ponavljanja tokom berbe 2017. i 2018. godine. Rezultati su pokazali da su genotipovi 25, 19 i 28 imali najveću dužinu lista, genotipovi 31, 22 i 23 broj listova po biljci, genotipovi 4, 18 i 27 broj semena po kapsuli i genotipovi 8, 11 i 7 masu semena. Masa semena je bila u pozitivnoj korelaciji sa dužinom lista, širinom lista i visinom biljke u zrelosti, brojem semena po kapsuli i masom 100 semena. Na broj listova po biljci uticala je dužina lista, širina lista i dužina grane. Pat analiza za masu semena pokazala je da broj grana po biljci, masa semena po kapsuli, broj semena po kapsuli i masa kapsule značajno doprinose prinosu semena. Indirektan doprinos karakteristika broju listova po biljci bio je mali u poređenju s direktnim uticajem. Dužina lista je imala najveći direktni uticaj na broj listova po biljci dok je njen najveći indirektni uticaj bio smanjenje mase semena. Direktni doprinos dužine lista broju listova po biljci bio je maskiran fenotipskom ekspresijom širine latice. Broj grana po biljci je pouzdan indeks za poboljšanje prinosa semena. Hibridizacija genotipova s najboljim učinkom za broj listova, sadržaj hlorofila u listu i prinos semena proizvešće nove sorte putem selekcije.

Ključne reči: juteni slez, fenotipska varijacija, korelacija karakteristika, selekcioni indeks, poboljšanje prinosa.

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