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Phenotypical characterization of cultivated eggplants (*Solanum melongena* L.), wild relatives and interspecific hybrids

G. K. M. M. K. Ranaweera[1*], H. Fonseka[2] and R.M. Fonseka[3]

[1] *Department of Crop Science, Faculty of Agriculture, University of Ruhuna, Matara, Sri Lanka*
[2] *Onesh Agriculture Pvt. Ltd. 100, Kent Road, Colombo 9, Sri Lanka*
[3] *Department of Crop Science, Faculty of Agriculture, University of Peradeniya, Kandy, Sri Lanka*

*Email: madhusankaranaweera111@gmail.com

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ABSTRACT

The study included twenty-two interspecific hybrids of wild relatives of eggplant from primary (S. incanum and S. insanum), secondary (S. lichtensteinii, S. anguivi, and S. dasyphyllum) and tertiary (S. torvum) gene pools, along with cultivated eggplant (Solanum melongena) and their parents. The experiment was laid on completely randomized design and plants were characterized using eggplant descriptor. Out of 18 characters, 12 (growth habit, leaf lobbing, leaf and calyx prickles, anthocyanin distribution, fruit length breadth ratio and color distribution) were significantly different (p<0.05) among cultivated eggplants, wild relatives and interspecific hybrids. The total variance in PCA components 1,2 and 3 accounted 50.5%, 20.9%, and 9.9 %, respectively. Three distinguish groups were found in factorial space for the components 1 and 2. Group 1 consisted of MEL1, MEL2, MEL3, MEL4, MEL5, MEL6, MEL8, MEL9 of cultivated eggplants and wild relatives of primary gene pool, INS3, ANG1 and TOR1 in secondary and tertiary genepools respectively. Group 2 accessions highly prickles, with small fruits INS1 from primary and DAS1 from the secondary genepool and interspecific hybrids MEL2×DAS1, MEL7×INS1, MEL2×INS1, MEL5×INS1, MEL6×INS3 associated with this group. Group 3 was made with remaining interspecific hybrids and INS2 from the primary genepool, LIC1 and ANG2 from secondary genepool of wild accessions. It can be concluded dominant alleles related to evaluating morphological characters are carried by the wild relatives. These hybrid materials would be the starting point for introgression breeding in eggplant for climate change they can also be useful as rootstocks against certain biotic and abiotic stress for grafting.

***Keywords**:* Descriptor, genepool, interspecific hybrid, *Solanum melongena* and wild relatives

INTRODUCTION

The eggplant is the most important vegetable crop in the world, in terms of nutritional and medicinal value. In relation with other vegetables, the leaves, fruits and roots have several distinct medicinal values in eggplants, tissue extracts have traditionally been used to treat asthma, bronchitis, cholera and dysuria, fruits and leaves are helpful in reducing cholesterol in the blood (Kashyap *et al*., 2003). Wild relatives of eggplant can grow a wide range of environmental conditions such as deserts with a wide range of temperatures, waterlogged, saline and swampy areas (Davidar *et al*., 2015; Knapp *et al*., 2013 and Lester and Hasan, 1991) besides, resistant to several major diseases (Daunay and Hazra, 2012; Rotino *et al*., 2014). Eggplant wild relatives are grouped, based on genetic relationships and cross ability into different gene pools known as primary, secondary or tertiary (Harlan and Wet, 1971). As *S. incanum* and *S. insanum,* can produce fertile hybrids with cultivated eggplants they are categorized under the primary genepool (Knapp *et al*., 2013). African and Southeast Asian species which resulting hybrids with different levels of fertility are under the secondary genepool (Daunay and Hazra, 2012; Rotino *et al*., 2014). The secondary genepool includes the closely related "eggplant clade", *S. lichtensteinii* and the sister "*anguivi* grade" such as *S. anguivi* and *S. dasyphyllum* (Plazas *et al*., 2016). Tertiary genepool includes species, which result in offspring with sterile or low fertility after embryo rescue or somatic hybridization. Tertiary genepool is an admixture of species from subgenus *Leptostemonum*, which include the old world as well as new world species (Daunay and Hazra, 2012; Rotino *et al*., 2014). Among this genepool, *S. elaeagnifolium*, is an invasive weed with a high ability to stand under drought conditions (Christodoulakis *et al*., 2009) moreover, *S. sisymbriifolium* and *S. torvum* are resistance to multiple diseases (Bletsos *et al*., 2003).

F1 Hybrids of eggplant cultivars that have been growing in greenhouses have a narrow genetic base compared to wild relatives (Mutegi *et al*., 2015; Vorontsova *et al*., 2013). However, wild relatives represent wide variation for resistance traits, which is highly valuable for eggplant breeding (Daunay and Hazra, 2012). Thus, wild relatives play a major role in the preparation of breeding materials having resilient to climate change (Dempewolf *et al*., 2014; Ranaweera *et al*.,2020). Although wild relatives of eggplants have been less utilized in breeding programs, this untapped genetic variation helps to widen the genetic base of eggplant to improve new varieties (Plazas *et al*., 2016). The morphological characterization is a basic step to identifying and effective utilization of wild relatives (Kaushik *et al*., 2016). Thus the experiment was conducted to characterize cultivated eggplants, wild relatives and their interspecific hybrids. Data from wild and cultivated species along with their interspecific hybrids, provide extensive information on the source of diversity, breeding potential and the transfer of key traits from wild relatives to future generations (Prohens *et al*., 2013) also identification potential roots stocks, which can be used as roots stock in grafting which are higher tolerant to biotic and abiotic stresses (Gisbert *et al*., 2011; Daunay and Hazra, 2012).

MATERIALS AND METHODS

The plant materials consisted of 9 accessions of *S melongena* cultivated eggplants originated from Ivory Coast (MEL1, MEL2, and MEL3), Sri Lanka (MEL4, MEL5, MEL6, and MEL9), South East Asia (MEL7) and Spain (MEL8). There are 8 accessions of wild species of primary gene pool *S. insanam* (INS1, INS2, and INS3), Secondary gene pool *S. anguivi*, *S. lichtensteinii*and *S. dasyphyllum* (ANG1, ANG2, LIC1, and DAS1) and Tertiary genepool *S. torvum* (TOR1) (Table 1). 22 interspecific hybrid progenies (Table 2) were obtained by crossing among the aforementioned cultivated eggplants and wild species.

15 plants per parental accessions and hybrids were grown during the *yala* (minor dry) season in 2019 at the experimental station, University of Peradeniya (WM2b). Plants were grown in polythene pots spaced at 60 cm x 90 cm, filled with media having a composition of 5:3:2:1 ratio (topsoil: compost: coir dust: half burn paddy husk) and the experiment was laid according to completely randomized design (CRD). All management practices were done according to the Department of Agriculture (DOA) recommendations. All plants were characterized using an eggplant descriptor ((IBPGR,1990) (Table 3). This descriptor described different traits of the whole plant, leaf, and fruit. Except

Table 1: Accessions of cultivated eggplant (*Solanummelongena*), wild relatives of the primary, secondary and tertiary genepools

Status	Gene pool	Species	Accession	Symbol	Origin
Cultivated		*S. melongena*	MEL1	M1	Ivory Coast
			MEL2	M2	Ivory Coast
			MEL3	M3	Ivory Coast
			MEL4	M4	Sri Lanka
			MEL5	M5	Sri Lanka
			MEL6	M6	Sri Lanka
			MEL7	M7	Commercial (SE Asia)
			MEL8	M8	Commercial (Spain)
			MEL9	M9	Commercial (Sri Lanka)
Wild relatives	Primary	*S. insanum*	INS1	IN1	Sri Lanka
			INS2	IN2	Sri Lanka
			INS3	IN3	Japan
	Secondary	*S. anguivi*	ANG1	AG1	Ivory Coast
			ANG2	AG2	Ivory Coast
		S. lichtensteinii	LIC1	LC1	South Africa
		S. dasyphyllum	DAS1	DS1	Uganda
	Tertiary	*S. torvum*	TOR1	TR1	Unknown (source: France)

Table 2: Interspecific hybrids between cultivated eggplant and wild relatives

	MEL1	MEL2	MEL3	MEL4	MEL5	MEL6	MEL7
INS1		M2×IN1	M3×IN1	M4×IN1	M5×IN1	M6×IN1	M7×IN1
INS2	M1×IN2	M2×IN2	M3×IN2		M5×IN2	M6×IN2	
INS3		M2×IN3	M3×IN3		M5×IN3	M6×IN3	M7×IN3
ANG1							
ANG2		M2×AG2					
LIC1				M4×LC1	M5×LC1	M6×LC1	
DAS1	M1×DS1	M2×DS1					
TOR1							

Table 3: Eggplant descriptor used for characterization

Eggplant descriptors	
Plant growth habit	1- Very upright, 7- Postrate
Leaf-blade lobes	1– Very weak, 9- Very strong
Leaf prickles	0- None, 9- Very many
Leaf length	3- (Short ~ 10 cm), 7- Long ~ 30 cm
Leaf width	3- Narrow ~5 cm, 7- Wide~ 15cm
Leaf tip angle	1-Very acute~ 15^0, 9- Very obtuse~ 160^0
General anthocyanin distribution	0-Absent, 7-Very high
Fruit size	1- Very small <15 g, 9- Very big (>1000g)
Fruit length/breadth ratio	1- Broader than long, 9- Several times longer than broad
Fruit apex shape	3- Protruded, 7- Depressed
Fruit curvature	0- None, 9- U shaped
Fruit shape (position of widest part)	3-About ¼ way from base tip, 7- Above ¾ way from base tip

for plant growth habit, five measurements per plant (per replication) were taken to obtain individual plant average.

Data were analyzed using SPSS software (version 22). Mean values of cultivated eggplants, wild relatives and interspecific hybrid groups were subjected to analysis of variance (ANOVA) and mean separation was done using student-newman-keuls (SNK) at p=0.05. Principal component analyses (PCA) were done using Euclidean distance for each character.

RESULTS AND DISCUSSION

Average values of 12 descriptors were significantly different ($p < 0.05$) among cultivated eggplants, wild relatives and interspecific hybrids out of 18 descriptors. Generally, leaf prickles, fruit calyx prickles, fruit color distribution, anthocyanin distribution of leaf vein and stem and leaf width less in cultivated eggplant compared to wild relatives and interspecific hybrids. Interspecific hybrids had significantly higher leaf prickles and fruit calyx prickles, leaf width, and anthocyanin distribution of stem and leaf veins. Fruit characters including fruit size, number of grooves present in cross-section, and length breadth ratio of wild relatives are significantly lower than cultivated eggplants and interspecific hybrids (Table 4).

The principal component analysis (PCA) performed with agro-morphological descriptors of parental accessions (cultivated and wild relatives) and their interspecific hybrids resulted in main 3 components that explained 81.4% of the total variance. Component 1, 2, and 3 accounted respectively, for 50.5%, 20.9%, and 9.9 % of the total variance.

The first component was negatively correlated with fruit shape (r= -0.618) nevertheless, it was positively correlated with other descriptors such as growth habit (r=0.731), anthocyanin distribution of stem (r=0.759), apex (r=0.721), calyx (r=0.631), leaf blade (r=0.58) and leaf width (r=0.724).The second component was positively correlated with

Table 4: Mean values, standard deviation (SD), and the probability of each morphological character of cultivated eggplant (*S melonogena*), wild relatives, and interspecific hybrids at 0.05 significant level.

Descriptor	Cultivated Eggplant Mean ± SE	Wild relatives Mean ± SE	Interspecific hybrids Mean ± SE	Probability
Growth habit	(5.07±1.48)^{b}	(4.72+-1.66)^{b}	(3.91+1.32)^{a}	0.000
Leaf Lobes	(4.85±1.07)^{a}	(5.45+1.50)^{ab}	(5.79+1.20)^{b}	0.002
Leaf prickles upper	(0±0)^{a}	(3.40+4.33)^{b}	(2.97+2.57)^{b}	0.000
Leaf apex shape	(3.71±0.97)	(4.36+1.29)	(4.10+1.12)	0.113
Leaf length	(4.28±0.97)	(3.63+1.29)	(4.25+1.37)	0.116
Leaf width	(4.96±0.79)^{a}	(4.63+1.46)^{a}	(5.44+0.83)^{b}	0.000
Stem anthocyanin	(1.28±1.84)^{a}	(0.95+1.86)^{a}	(4.04+2.38)^{b}	0.000
Calyx anthocyanin	(0.75±2.20)	(0.40+1.05)	(1.07+1.46)	0.183
Leaf vein anthocyanin	(1.07±1.46)^{a}	(0.81±1.36)^{a}	(3.44±2.49)^{b}	0.000
Leaf blade anthocyanin	(1.07±1.46)	(0.81±1.36)	(3.44±2.49)	0.088
Fruit size	(4.42±1.06)^{b}	(2.27±0.98)^{a}	(4.08±1.18)^{b}	0.000
Fruit length breadth ratio	(5.60±2.88)^{b}	(2.54±0.85)^{a}	(4.69±1.75)b	0.000
Fruit apex shape	(5.57±1.70)	(6.00±1.60)	(6.18±1.24)	0.126
Fruit color distribution	(3.42±2.63)^{a}	(5.09±2.42)^{b}	(5.55±2.41)^{b}	0.000
Fruit calyx prickles	(0.00± 0.00)^{a}	(0.63±1.04)^{a}	(2.91±2.75)^{b}	0.000
Fruit curvature	(0.64±1.25)^{b}	(0±0)^{a}	(0±0)^{a}	0.000
Fruit shape	(5.42±0.83)	(5.00±0)	(5.14±0.82)	0.114
Fruit cross section	(5.28±2.41)^{b}	(3.54±1.96)^{a}	(5.00±1.11)^{b}	0.000

Table 5: Values represent the correlation coefficients for the three first principal components in the collection of eggplant (*S. melongena*), wild relatives, and interspecific hybrids for each trait. Correlation with absolute values e"0.5 in bold

Trait	Component		
	1	2	3
Growth habit	0.731	-0.428	-0.008
Leaf Lobes	0.293	0.579	0.018
Leaf prickles upper	0.076	0.615	0.005
Leaf apex shape	0.411	-0.177	0.540
Apex anthocyanin	0.721	-0.138	-0.366
Stem anthocyanin	0.759	0.067	-0.113
Calyx anthocyanin	0.631	-0.052	-0.385
Leaf vein anthocyanin	0.818	-0.006	-0.198
Leaf blade anthocyanin	0.580	-0.146	-0.117
Fruit size	0.482	-0.167	0.701
Fruit length breadth ratio	0.323	-0.622	0.352
Fruit apex shape	0.087	0.411	-0.600
Fruit color distribution	0.563	0.236	-0.112
Fruit calyx prickles	0.192	0.566	-0.074
Fruit curvature	-0.142	-0.562	0.244
Fruit shape	-0.618	-0.113	-0.130
Leaf length	-0.019	0.516	0.386
Leaf width	0.724	0.495	0.494
Fruit cross section	0.319	-0.113	0.691

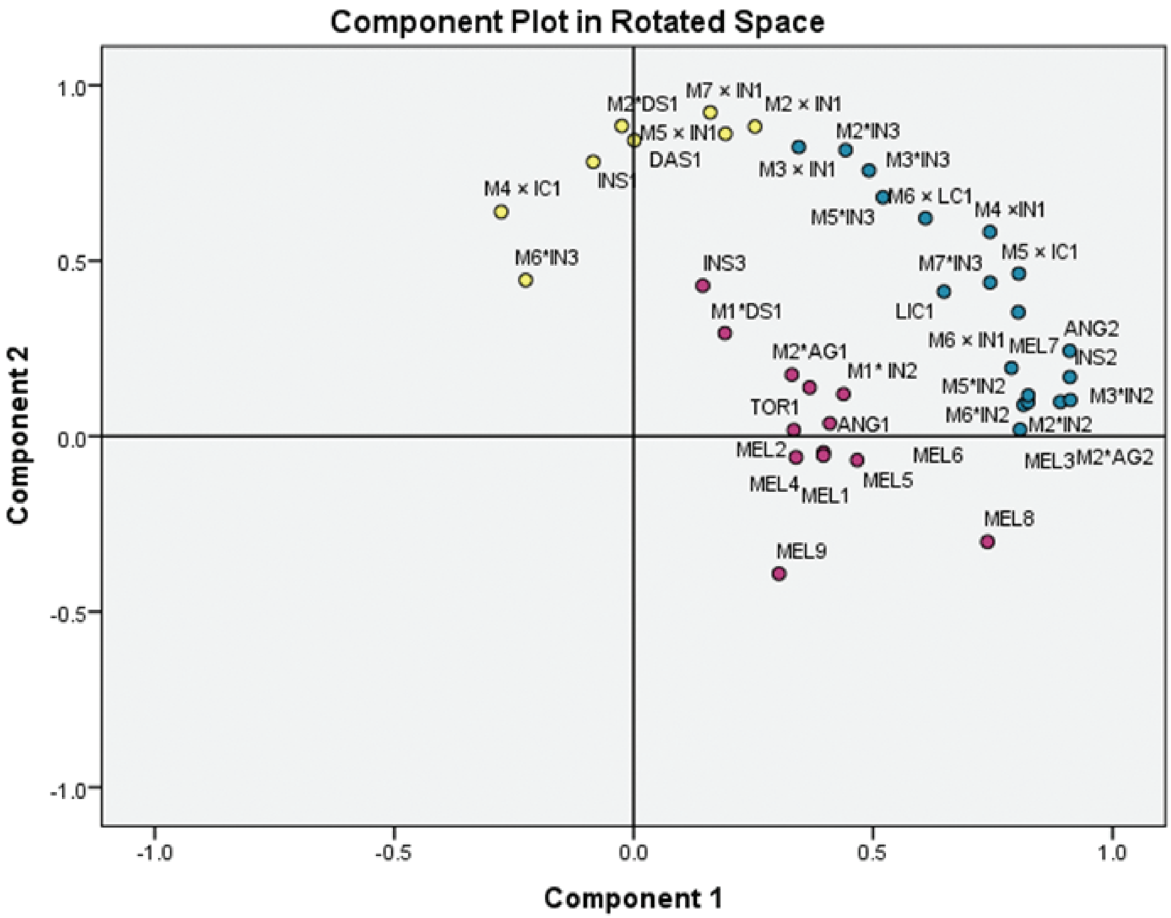

Fig. 1: Distribution of accessions of cultivated eggplant, wild relatives and their interspecific hybrids groups determined by the factorial components 1 and 2 of the PCA

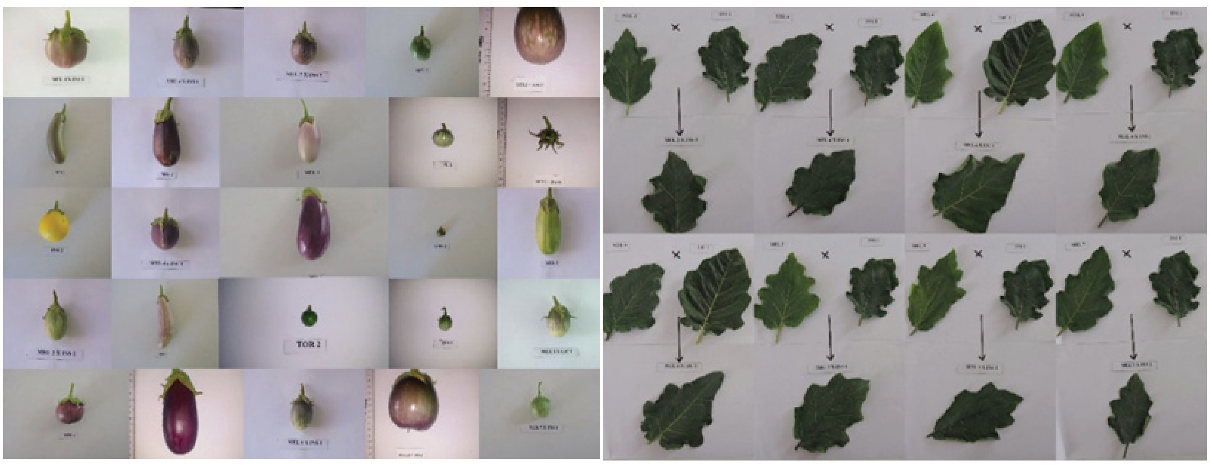

Fig. 2: Fruits and leaves of wild relatives, cultivated eggplants and their interspecific hybrids showing different degrees of morphological characters

leaf lobes (r=0.579), prickles of leaf blade (r=0.615) and fruit calyx (r=0.566) and leaf length (r=0.516) furthermore fruit length breadth ratio (r= 0.622) and fruit curvature (r= 0.562). Leaf apex shape (r=0.540), fruit size(r=0.701) and fruit cross section (r=0.691) was positively correlated with third component and fruit apex shape (r=0.600) negatively correlated (Table 5).

Three distinguished groups were identified in factorial space when drawing a graph with the axes of component 1 and 2 (Fig. 1). Group 1 consisted of MEL1, MEL2, MEL3, MEL4, MEL5, MEL6, MEL8 and MEL9 of cultivated eggplants, and primary gene pool of wild relatives INS3, ANG1, and TOR1 in secondary and tertiary genepools, interspecific hybrids of M1×DS1, M2×AG1 and M1×IN2, also included in this group. This group is with less leaf and fruit calyx prickles, and larger fruit size. Group 2 accessions highly prickles, with small fruits INS1 from primary andDAS1 from the secondary genepool was associated with this group. Interspecific hybrids such as M2×DS1, M7×IN1, M2×IN1, M5×IN1and M6×IN3 also associated with this group. Group3 was made with remain interspecific hybrids and wild relatives of INS2 from the primary genepool, LIC1 and ANG2 form secondary genepool of wild accessions. This represents intermediate characters compared to wild and cultivated accessions.

According to the results, many differences were found among cultivated eggplant, wild relatives and their interspecific hybrids for the morphological traits. Generally, wild varieties can withstand semi-arid and arid environmental conditions (Knapp *et al*., 2013) even though when growing wild relatives and interspecific hybrids under favorable conditions as same cultivated plants, they expressed high vigor than average values for plant morphological features which seems to be an important point to select rootstocks for grafting (Gisbert *et al*., 2011). Reported results showed interspecific hybrids with high prickliness in leaves and fruit calyx, confirming that the prickliness allele was recessive in cultivated eggplants (Doganlar *et al*., 2002; Gramazio *et al*., 2014). Fruit size is a very important trait that is primarily character which consider in breeding programs (Daunay and Hazra, 2012). According to Meyer *et al*. (2012) fruit size varies highly among cultivated eggplants which are becoming prominent with domestication. The fruit size of interspecific hybrids is intermediate among the values of cultivated eggplant and their wild relatives. Even though those values are mostly closer to wild relatives, which confirms wild relatives carrying the responsible genes for fruit characteristics (Doganlar *et al*., 2002). Nevertheless, small fruit can be eliminated by backcrossing in several generations. According to Prohens *et al*. (2013), fruit size can be enhanced by using *S. incanum* even in the first back cross. According to Rotino *et al*. (2014), wild relatives of eggplants used in breeding resulted in undesirable traits such as small fruit size, leaf prickliness, calyx prickliness, etc. As *S. anguivi* and *S. torvum* are with fewer prickles those provide favorable combinations to a breeder. The principal component analysis provides better information regarding the genetic control mechanism of morphological traits. Most of the interspecific hybrids are closer to the wild parent than the cultivated parent. This suggests that the dominant alleles for morphological traits are carrying by their wild parents.

CONCLUSIONS

For the evaluation morphological descriptors of interspecific hybrids are more related to wild parent as dominant alleles related to evaluate morphological characters evaluated in the study are carried by wild relatives. These hybrid materials are the starting point for introgression breeding in eggplant and can be utilized as rootstocks for grafting. Finally, the information reported may have potential value in the development of new cultivars, which are adapted to climate change.

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