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Genetic variation, heritability and genetic advance of eggplant accessions (*Solanum* spp.)

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Abstract

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Eggplants are economically important vegetable crops in many parts of the world especially Asia and Africa, where their fruits and leaves play a vital role in many diets. An experiment was conducted to study the genetic variability, heritability and genetic advance for 24 quantitative characters in eggplant. Thirty three accessions were planted in pots on the research field of the Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Kumasi using Completely Randomized Design. The analysis of variance showed significant genetic variation among the accessions for the characters studied indicating the presence of adequate amount of variability. High phenotypic and genotypic coefficient of variation (PCV and GCV) were observed for plant height, days to first flower opening, days to 50% flower opening, fruit calyx prickles, number of fruits/plant, fruit weight/plant, fruit yield/plant and number of seeds/fruit. High heritability coupled with high genetic advance were observed for fruit length, fruit breadth, fruit length and breadth ratio, fruit pedicel thickness, fruit pedicel prickles, fruit calyx prickles and number of locus/fruit. Thus, these characters could be included in the selection criteria for eggplant improvement.

Keywords: Solanum species; eggplants; accessions; genetic variability; heritability; genetic advance
Abbreviations: PV – phenotypic variation; GV – genotypic variation; PCV – phenotypic coefficient of variation; GCV – genotypic coefficient of variation

Introduction

Eggplants (*Solanum* spp.) are one of the most important fruit vegetables with world production exceeding 49.4 million tonnes (FAO, 2015). With its great phenotypic variability, eggplant fruits present a good source of dietary fiber and vitamins (vitamins A, B1 and B6), and provides substantial quantities of minerals such as phosphorus, potassium, calcium and magnesium (Raigón et al., 2008; Okmen et al., 2009). Further, they contain higher content of free reducing sugars, anthocyanin, phenols, glycoalkaloids and amide proteins which is linked to their medicinal properties (Mariola et al., 2013; Sabolu et al., 2014). Consequently, they are used as a staple food in many tropical and subtropical countries and are one of the 35 crops judged to be most important for food security (Fowler et al., 2003). In spite of all these attributes, cultivated eggplants are susceptible to numerous diseases and parasites, including soilborne pathogens and pests (Collonnier et al., 2001; Bletsos et al., 2003; Daunay, 2008). Moreover, they have narrow genetic base compared to their wild relatives such as *S. torvum* (ST004-03) and *S. anguivi* (San005-01) that have much higher genetic diversity, and are a source of variation for resistant genes that can be utilized in eggplant breeding (Weese & Bohs, 2010; Daunay & Hazra, 2012; Vorontsova et al., 2013; Mutegi et al., 2015).

However, for a plant breeder to carry out an effective breeding programme, he/she should be abreast with the quantum of genetic diversity available in a base population for exploitation and the extent to which the desirable traits are heritable (Syafrudin et al., 2016). The collection, selection and estimation of genetic variability among cultivars of eggplants is essential for directing crosses, evaluating available germplasm and for maintaining appropriate range of genetic diversity (Adeniji et al., 2013), while broadening the genetic base of cultivated varieties. Nonetheless, selection will only be effective when there is significant amount of genetic variability among the individual breeding materials. The objective of this study was therefore to assess the variability, heritability and genetic advance of yield and its components in eggplant which would eventually help in the selection of desired traits that may contribute in the improvement of eggplants in Ghana.

Materials and Methods

Experimental materials and site

Thirty three (33) eggplant accessions were collected from Central, Western, Greater Accra, Ashanti and Northern regions of Ghana. They included twelve (12) *S. aethiopicum* accessions, eight (8) *S. melongena* accessions, seven (7) *S. macrocarpon* accessions and four (4) *S. torvum* and two (2) *S. anguivi* accessions representing wild types (Table 1). The

Table 1. List of eggplant accessions used for genetic diversity studies

Accessions	Collection site	Region	Taxon	Status
San005-01	Atonsu	Ashanti	San	Wild
San005-02	Atonsu	Ashanti	San	Wild
SA002-01	Bunso/ PGRRI	Eastern	SA (Gilo gp)	Cultivated
SA002-02	Bunso/ PGRRI	Eastern	SA (Gilo gp)	Cultivated
SA002-03	Bunso/ PGRRI	Eastern	SA (Gilo gp)	Cultivated
SA002-04	Kejetia	Ashanti	SA (Gilo gp)	Cultivated
SA002-05	Kejetia	Ashanti	SA (Gilo gp)	Cultivated
SA002-06	Kejetia	Ashanti	SA (Gilo gp)	Cultivated
SA002-07	Bunso/ PGRRI	Eastern	SA (Shum gp.)	Semi-cultivated
SA002-08	Bunso/ PGRRI	Eastern	SA(Shum gp)	Semi-cultivated
SA002-09	Bole	Northern	SA (Kumba gp)	Cultivated
SA002-10	Bawku	Northern	SA (Kumba gp)	Cultivated
SA002-11	Bawku	Northern	SA (Kumba gp)	Cultivated
SA002-12	Yedi	Northern	SA (Kumba gp)	Cultivated
ST004-01	Adenta	Greater Accra	ST	Wild
ST004-02	Abura	Cental	ST	Wild
ST004-03	Atonsu	Ashanti	ST	Wild
ST004-04	Juaboso	Western	ST	Wild
SM001-01	Abura	Central	SM	Cultivated
SM001-02	Juaboso	Western	SM	Cultivated
SM001-03	Abura	Central	SM	Cultivated
SM001-04	Mankesim	Central	SM	Cultivated
SM001-05	Mankesim	Central	SM	Cultivated
SM001-06	Dome	Greater Accra	SM	Cultivated
SM001-07	Abura	Central	SM	Cultivated
SM001-08	Mankesim	Central	SM	Cultivated
SMA003-01	Abura	Central	SMA	Cultivated
SMA003-02	Keta	Volta	SMA	Cultivated
SMA003-03	Ajumako Besease	Central	SMA	Semi-wild
SMA003-05	Juaboso	Western	SMA	Semi-wild
SMA003-06	Denu	Volta	SMA	Cultivated
SMA003-07	Denu	Volta	SMA	Cultivated
SMA003-08	Denu	Volta	SMA	Cultivated

San – *S. anguivi*, SM – S. *melongena*, SMA – *S. macrocarpon*, ST – *S. torvum* and SA – *S. aethiopicum* seeds of these accessions were sown in trays and seedlings were transplanted into pots (containing 4 kg of steam-sterilized soil) on the field four weeks after emergence at the research field of the Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Ghana.

Experimental design

The experiment was laid down in a Completely Randomized Design with four replications. Pots were spaced 60 cm apart within the same accession and 75 cm apart between different accessions to accommodate 99 plants per replicate and 396 plants on the field. All standard recommendations and agricultural practices of eggplant productions were adhered to for normal plant growth.

Data collection and analyses

Data were recorded from selected plants from each of the accessions for leaf length (cm), leaf width (cm), leaf prickle, plant height (cm), stem girth (mm), plant branching, days to 1st flower opening, days to 50% flowering, fruit pedicle length (cm), fruit pedicle thickness (cm), fruit length (cm), fruit breadth (cm), fruit length/breadth ratio, fruit calyx prickles, fruit pedicle prickles, number of fruit per plant, fruit weight per plant (g), fruit yield/plant (kg/ha), number of seeds/fruit, seed diameter (cm), seed weight (g) and number of locules/fruit using descriptors for eggplant (IBPGR, 1990). Data collected were subjected to Analysis of Variance (ANOVA). The Analyses were carried out using GenStat statistical software programme (11th edition).

Estimation of variance components

The phenotypic and genotypic variances, phenotypic and genotypic coefficient of variation were estimated according to the method suggested by Kwon & Torrie (1964) using the formula below;

$$GV = \frac{\text{Genotype Mean Square (GMS)} - \text{Error Mean Square (EMS)}}{\text{Number of replication (r)}}, \quad (1)$$

where GV = Genotypic Variance.

$$PV = \text{Genotypic variance} + \text{Environmental variance}, \quad (2)$$

where PV = Phenootypic Variance.

Genotypic and Phenotypic coefficient of variation were calculated as:

$$GCV = \sqrt{\frac{GV}{\bar{x}}} \times 100 \quad (3)$$

$$PCV = \sqrt{\frac{PV}{\bar{x}}} \times 100, \quad (4)$$

where: GCV% = Genotypic Coefficient of variation; GV = Genotypic Variance; PCV % = Phenotypic Coefficient of Variation; PV = Phenotypic Variance; EV = Environmental Variance; Environmental variance = Error mean square.

Estimation of heritability in broad sense and genetic advance

Heritability in the broad sense was calculated by the formula described by Allard (1960) as follow:

$$h^2b = \frac{GV}{PV} \times 100, \quad (5)$$

where: h^2b = Heritability (broad sense); GV = Genotypic variance and PV = Phenotypic variance.

The expected genetic advance and genetic advance in percentage of mean was calculated by using method described by (Falconer, 1989):

$$GA = \sqrt[K]{PVh^2b}, \quad (6)$$

where: K = 2.06 at 5% selection intensity for the trait; PV = Phenotypic Variance for the trait; h^2b = Broad sense heritability of the trait; Genetic advance as percentage of mean (GAM) was calculated as:

$$GAM\% = \frac{GA}{\bar{x}} \times 100, \quad (7)$$

where: GA=expected genetic advance and = grand mean of a character.

Results and Discussion

Analysis of variance

The mean squares of the analysis of variance showed that accessions varied significantly ($P \leq 0.01$) for most traits under study (Table 2). This indicates the presence of sufficient natural variation among accessions for the various traits measured. The distinct diversity observed for fruit, inflorescence and seed characteristics suggest the scope for selecting suitable initial breeding material for effective genetic improvement as well as in-situ and ex-situ conservation of eggplant in Ghana. Boyaci et al. (2015) and Solaimana et al. (2015) also reported on adequate variation for quantitative traits in cultivars of eggplant. The application of Turkeys test to determine the extent of variability with respect to the different traits indicated that accession SA002-07 had the lowest number of days to first (44days) and 50% (48 days) flower opening and the lowest number of seeds/fruit (34 seeds) (Table 3). Accession ST004-04 had the maximum number of days to first and 50% flower opening and plant branching (19) while accession SM001-08 showed the highest number of seeds/fruit (1544 seeds). Further, SM001-04 recorded the highest mean values for fruit length (12.60 cm), fruit weight/plant (631.10 kg) and plant height (60.83 cm) whereas accessions SM002-07 and San001-02 showed maximum average values for number of fruits/plant (9573) and fruit breadth (8.41 cm), respectively (Table 3). Thus the plant breeder can breed for earliness or lateness using accessions SA002-07 and ST004-04; while for high fruit yield selection can be made from accessions SM001-07, SMA005-06, San005-02, SM002-04 and San001-02.

Table 2. Analysis of variance for quantitative characters in eggplant

SOV	Df	LL	LW	LP	PL	PH	SG	PB	DF[1st]
Acc	32	31.37**	19.08**	17.05**	17.05**	460.96**	0.14**	22.32**	2150.61**
Error	99	7.72	6.63	6.26	2.05	9.2	0.001	0.29	61.33
SOV	Df	DF50%	FL	FB	FL/FB	FPL	FPT	FCP	FPP
Acc	32	2022.04**	41.71**	20.58**	1.15**	7.57**	0.59**	169.66**	19.90**
Error	99	52.36	0.31	0.27	0.06	0.09	0.01	0.11	0.04
SOV	Df	NL/F	RFCL	NF/P	FW/P	FY/P	NS/F	SS	SW
Acc	32	23.25**	9.77**	3565506**	68708.16**	27149.00**	656108.00**	0.012**	0.202**
Error	99	0.48	0.09	11018401	581.5	5151525	9491	0.001	0.05

LL – leaf length, LW – leaf width, LP – leaf prickle, PL – petiole length, FL- fruit length, FB – fruit breadth, FPL – fruit pedicle length, FPT – fruit pedicle thickness, FCP – fruit calyx prickles, FPP – fruit pedicel prickles, NL/F – number of locules/fruit, RFCL – relative fruit calyx length, NF/P – number of fruit/ plant, FW/P – fruit weight/plant, FY/P – fruit yield/plant, NS/F – number of seeds/ fruit, PB- plant branching, PH – plant height at flowering, SG – stem girth, DF (1[st]) – days to first flowering, DF (50%) – days to 50% flowering, SS- seed size and SW – 100 seed weight, Acc – accession, ** – significant at probability level of 0.01, Df – Degree of freedom.

Table 3. Quantitative characteristics of the eggplant accessions

Accession	LL (cm)	LW (cm)	LP	P L (cm)	PH (cm)	SG (mm)	PB	DF (1st)	DF (50%)	FL (cm)	FB (cm)	FL/FB	FPL (cm)	FPT (cm)	FCP	FPP	NL/F	RFCL (%)	NF/P	FW/P (g)	Yield Kg/ha	NS/F	SS (cm)	SW (g)
San005-01	16.10 e	15.24 hijkl	0.00 a	2.93 b	49.44 jkl	0.42 b	8.67 ab	79.30 m	85.00 b	1.16 a	0.90 a	1.28 cdefg	0.70 a	0.28 bc	0.00 a	0.00 a	1.40 ab	30.66 ij	148.11 g	32.10 a	595.04 a	46.00 a	0.23 abcde	0.12 a
San005-02	13.39 ab	10.77 de	2.96 e	3.74 c	52.28 mno	0.91 klm	9.78 cdefg	84.30 n	85.70 b	1.12 a	0.94 ab	1.21 cdef	0.87 ab	0.13 a	0.00 a	0.00 a	1.40 ab	31.45 j	233.00 ef	90.20 b	1672.04 b	53.00 ab	0.21 abcd	0.14 a
SA002-01	12.53 a	9.80 cd	1.407b	9.39 l	40.66 ef	0.79 ghi	10.22 defghij	88.70 b	92.30 c	6.02 de	4.07 cde	1.48 fghi	2.24 jk	0.77 kl	0.00 a	0.00 a	7.60 kl	36.77 kl	7.89 a	144.40 c	2676.74 c	514.70 fg	0.28 defgh	0.10 a
SA002-02	20.02 lmno	18.02 mn	0.00 a	7.61 h	39.97 ef	0.84 ij	8.89 abc	98.30 fgh	107.30 hijk	6.84 fg	4.72 f	1.46 efghi	2.40 jk	0.58 hij	0.00 a	0.00 a	5.20 fgh	15.16 a	15.00 a	322.70 h	5981.89 h	263.30 cd	0.23 abcde	0.15 a
SA002-03	16.31ef	13.50 ghij	0.00 a	7.31 fgh	32.43 d	0.92 lm	8.44 a	93.00 cd	97.70 cde	6.36 ef	4.72 f	1.35 defgl	2.24 jk	0.58 hij	0.00 a	0.00 a	5.40 gh	23.30 ef	12.11 a	280.80 fg	5205.19 fg	340.00 cde	0.37 fgh	0.14 a
SA002-04	14.29 bcd	13.26 ghi	0.00 a	5.40 d	40.21 ef	0.93 lm	10.78 hijk	102.00 hijl	108.70 ijk	2.06 b	1.56 b	1.37 defgh	1.74 fgh	0.36 cde	0.00 a	0.00 a	4.60 efg	31.76 j	33.78 bc	154.50 cde	2863.97 cde	538.30 fg	0.25 bcdef	0.17 a
SA002-05	18.61 ij	16.79 klm	1.48 b	6.13 e	52.87 no	0.84 ij	10.22 defghij	104.30 ijk	106.70 ghijk	2.92 b	2.70 b	1.28 cdefg	1.52 defg	0.40 cdef	0.00 a	0.00 a	4.60 efg	35.56 k	41.44 c	140.30 c	2600.75 c	510.70 fg	0.21 abc	0.24 a
SA002-06	20.65 op	19.65 n	2.33 e	5.53 d	52.30 mno	1.00 n	11.78 lm	105.00 jk	111.70 k	1.62 ab	1.52 ab	1.16 bcdef	1.28 cde	0.37 cde	0.00 a	0.00 a	4.80 efg	51.83 p	38.56 c	192.50 e	3568.37 e	373.30 cdef	0.30 efgh	1.10 b
SA002-07	11.99a	4.51a	0.00 a	1.80 a	50.37 jklmn	0.27 a	13.33 n	45.00 a	49.00 a	1.52 ab	1.30 ab	1.17 bcde	0.96 abc	0.16 ab	0.00 a	0.00 a	4.20 de	20.69 e	108.44 d	57.70 ab	1069.59 ab	32.70 a	0.30 efgh	0.28 a
SA002-08	11.17a	6.51 ab	0.00 a	1.79 a	38.73 e	0.46 bc	10.00 defghi	42.30 a	48.30 a	1.52 ab	1.40 ab	1.15 abcde	1.16 bcd	0.32 cd	0.00 a	0.00 a	1.00 a	20.17 de	102.78 d	57.60ab	1067.73ab	51.00 ab	0.27 cdefg	0.32 a
SA002-09	14.99d	11.97 defg	0.00 a	6.19 e	20.13 a	0.43 b	9.89 defgh	96.00 def	99.30 def	4.92 c	4.74 f	1.26 cdefg	1.38 def	0.44 defg	0.00 a	0.00 a	8.00 lm	18.95 cd	4.56 a	135.90 c	2519.18 c	403.30 def	0.23 abcde	0.26 a
SA002-10	17.02fg	13.93 ghij	0.00 a	6.43 e	30.88 cd	0.75 g	13.78 n	103.00 ijk	105.30 ghij	3.72 b	3.84 cd	1.01 abc	1.74 fgh	0.46 efgh	0.00 a	0.00 a	6.40 ij	16.50 b	13.67a	188.20 de	3488.66 de	458.30 efg	0.25 bcdef	0.14 a
SA002-11	14.94cd	12.62 efg	0.00 a	6.30 e	24.70 b	0.62 f	10.56 fghijk	94.00 de	101.70 efg	4.94 c	5.78 g	0.84 ab	1.72 fgh	0.52 fghi	0.00 a	0.00 a	8.20 lm	16.42 b	6.56 a	139.80 c	2591.47 c	887.30 ijkl	0.35 h	0.23 a
SA002-12	14.94 cd	13.04 fgh	0.00 a	5.18 d	24.09 b	0.47 bcd	9.56 bcde	105.70 k	107.30 hijk	4.66 c	5.52 g	0.83 a	1.52 defg	0.46 efgh	0.00 a	0.00 a	8.60 mn	18.78 c	6.22 a	145.30 c	2693.43 c	814.00 ijk	0.33 gh	0.25 a
ST004-01	16.46 ef	15.74 jkl	9.26 c	6.45 e	46.10 hi	0.84 ij	13.44 n	151.70 l	154.00 l	1.62 ab	1.26 ab	1.29cdefgl	1.53 defg	0.34 cde	0.00 a	0.00 a	2.00 bc	36.28 kl	233.78 ef	254.70 f	4721.37 f	228.30 c	0.18 ab	0.13 a
ST004-02	19.10 jk	18.69 mn	10.19 d	7.53 gh	54.10 op	0.94 m	17.78 o	151.30 l	154.70 l	1.56 ab	1.20 ab	1.43 defgl	1.54 defg	0.34 cde	0.00 a	0.00 a	2.60 c	30.85 ij	222.78 e	257.60 f	4775.13 f	219.00 c	0.17 a	0.12 a
ST004-03	19.61 klmn	18.30 mn	10.00 cd	7.03 f	59.62 q	0.97 mn	17.33 o	152.30 l	154.00 l	1.58 ab	1.18 ab	1.37 defgh	1.59 efg	0.27 bc	0.00 a	0.00 a	2.20 bc	25.30 f	232.89 ef	252.80 f	4686.15 f	216.00 bc	0.20 abc	0.12 a
ST004-04	19.53 klm	18.38 mn	9.74 c	7.17 fg	56.41 p	0.87 jkl	17.33 o	153.30 l	154.70 l	1.58 ab	1.28 ab	1.30 cdefg	1.60 efg	0.34 cde	0.00 a	0.00 a	3.60 d	30.93 ij	248.44 f	285.10 fgh	5284.90 fgh	218.70 c	0.17 a	0.13 a
SM001-01	17.39 gh	17.07 klm	0.00 a	9.59 ij	31.18 cd	0.84 ij	9.44 bcd	95.00 def	102.70 efgh	7.38 g	3.62 c	1.99 j	4.00 m	0.62 ij	0.00 a	0.00 a	6.00 hi	40.93 n	9.44 a	306.70 gh	5685.30 gh	893.70 jkl	0.23 abcde	0.25 a
SM001-02	18.05 hi	15.13 hijk	0.00 a	10.13 kl	49.27 jk	0.76 g	10.44 efghijk	102.00 hijl	108.30 ijk	10.30 l	6.66 h	1.58 ghi	4.82 n	1.33 op	0.00 a	0.00 a	4.80 efg	36.84 lm	9.56 a	421.80 ij	7818.91 ij	961.30 kl	0.27 cdefg	0.38 a
SM001-03	18.27 i	15.29 hijkl	3.10 f	9.83 jk	50.09 jklmn	0.84 ij	10.67 ghijk	105.30 jk	110.70 jk	6.98 fg	4.34 def	1.78 ij	4.80 n	1.36 p	0.00 a	0.00 a	6.40 ij	30.09 i	10.44 a	282.70 i	7094.11 i	1025.70 l	0.29 efgh	0.24 a
SM001-04	19.44 kl	15.14 hijk	0.00 a	9.40 i	60.53 q	0.76 gh	11.33 klm	97.70 efg	104.70 fghi	12.82 j	3.77 cd	4.29 k	4.94 n	0.98 m	0.00 a	0.00 a	3.60 d	26.61 gh	17.78 ab	638.60 k	11837.73 k	722.70 hi	0.27 cdefg	0.93 b
SM001-05	21.13 p	17.22 klm	0.00 a	10.31 l	52.23 lmno	0.92 lm	11.22 kl	92.70 bcd	104.70 fghi	9.94 l	8.06 ij	1.42 defgh	4.28 m	1.20 no	0.00 a	0.00 a	9.20 n	38.77 n	9.44 a	384.90 i	7134.89 i	1248.30 m	0.28 defgh	0.24 a
SM001-06	20.55 op	17.48 lmn	0.00 a	9.96 jkl	49.97 jklm	0.82 hij	11.00 jkl	102.00 hijl	106.00 ghij	11.90 j	6.46 h	1.56 ghi	5.00 n	1.58 q	0.00 a	0.00 a	10.60 o	38.04 mn	5.00 a	433.60 j	8037.64 j	294.00 cde	0.28 defgh	0.33 a
SM001-07	20.23 mno	15.36 ijkl	0.00 a	11.34 m	42.49 fg	0.85 ijk	10.11 defghij	98.30 fgh	106.30 ghijk	8.36 h	8.43 j	1.18 cdef	4.76 n	1.28 op	0.00 a	0.00 a	7.00 jk	46.73 o	8.33 a	408.80 ij	7577.93 ij	1449.00 n	0.35 h	0.33 a
SM001-08	20.48op	16.60 klm	0.00 a	9.65 ij	48.17 ij	0.76 g	10.22 defghij	102.30 hijl	106.00 ghij	6.44 ef	4.20 cdef	1.62 hi	4.78 n	1.14 n	0.00 a	0.00 a	8.40 lmn	45.94 o	4.33 a	272.30 fg	5047.63 fg	1458.30 n	0.27 cdefg	0.38 a
Sma003-01	20.27 no	12.32 efg	0.00 a	2.46 b	52.07 klmno	0.55 e	10.89 ijkl	101.30 ghi	109.00 ijk	8.49 h	7.71 l	1.10 abcd	3.16 l	0.98 m	0.00 a	0.00 a	5.21 fgh	46.37 o	2.67 a	147.10 cd	2726.79 cd	813.70 ijk	0.20 abc	0.27 a
Sma003-02	14.17 b	10.78 def	0.00 a	5.21 d	52.62 mno	0.66 f	10.67 ghijk	100.30 ghi	106.00 ghij	5.68 d	4.72 f	1.01 abc	2.16 ijk	0.70 jk	0.00 a	0.00 a	5.00 efg	54.80 p	10.60 o	151.30 cde	2804.65 cde	1246.70 m	0.28 defgh	0.38 a
Sma003-03	19.77 klmn	6.85 b	19.96 g	3.05 b	29.19 c	0.53 de	12.22 m	103.70 ijk	108.70 ijk	7.00 fg	7.00 h	1.19 cdef	3.02 l	0.82 kl	32.40 c	11.20 c	3.60 d	72.04 r	7.00 jk	275.80 fg	5112.51 fg	744.70 hij	0.20 abc	0.36 a
Sma003-05	19.43 kl	17.02 klm	3.93f	4.04 c	39.46 e	0.77 gh	9.67 cdef	105.00 jk	105.70 ghij	7.32 g	6.54 h	1.15 abcde	2.54 k	0.86 lm	20.20 b	6.60 b	4.40 def	65.65 q	8.40 lmn	164.70 cde	3053.04 cde	580.00 gh	0.25 bcdef	0.37 a
Sma003-06	11.29a	8.35 bc	0.00 a	4.09 c	52.47 mno	0.46 bc	11.00 jkl	89.00 bc	97.30 cde	4.82 c	4.00 cde	1.15 abcd	1.74 fgh	0.59 hij	0.00 a	0.00 a	4.20 de	37.00 lm	5.78 a	152.30 cde	2823.19 cde	874.00 ijkl	0.25 bcdef	0.33 a
Sma003-07	18.10 hi	10.59 cde	0.00 a	2.98 b	44.10 gh	0.77 gh	10.11 defghij	93.00 cd	96.00 cd	4.88 c	4.60 ef	1.12 abcd	1.78 ghi	0.78 kl	0.00 a	0.00 a	6.00 hi	27.83 h	7.33 a	142.30 c	2637.82 c	780.00 ij	0.30 efgh	0.38 a
Sma003-08	14.23 bc	10.98 def	0.00 a	3.29 b	32.59 d	0.50 cde	9.78 cdefg	88.70 b	98.70 de	4.900 c	4.20 cdef	1.19 cdef	2.10 hij	0.55 ghi	0.00 a	0.00 a	5.20 fgh	25.90 fg	5.44 a	135.40 c	2509.91 c	876.70 ijkl	0.28 defgh	0.36 a

LL – leaf length, LW – leaf width, LP – leaf prickle, PL – petiole length, FL – fruit length, FB – fruit breadth, FPL – fruit pedicle length, FPT – fruit pedicle thickness, FCP – fruit calyx prickles, FPP – fruit pedicel prickles, NL/F-number of locules/fruit, RFCL – relative fruit calyx length, NF/P- number of fruit/ plant, FW/P- fruit weight/plant, FY/P – fruit yield/plant, NS/F – number of seeds/ fruit, PB – plant branching, PH- plant height at flowering, SG – stem girth, DF (1[st]) – days to first flowering, DF (50%) – days to 50% flowering, SS – seed size and SW – 100 seed weight. Means with same letters within a column do not differ significantly (P < 0.01) by Tukey's test.

Mean and range

The eggplant accessions showed wide range of variation for all quantitative characters and all traits presented wide ranges between the minimum and maximum mean values (Table 4). For example, the number of leaf prickles on upper surface of the leaf ranged from 0 to 19 with mean of 2 prickles while number of primary branches/plant, days to first flowering and 50% flowering ranged from 8 to 17, 42 to 153 and 48 to 154 with mean values of 11 branches, 100 and 105 days for flowering, respectively (Table 4). Fruit length and fruit breadth also varied from 1.12 cm to 12.82 cm and 0.90 cm to 8.43 cm with mean values of 5.24 and 4.03. Fruit yield/plant ranged from 59.69 to 11.70 ha with an average of 4241ha and that of fruit pedicel length, fruit pedicel breadth and number of seeds/fruit ranged from 0.7 cm to 5 cm, 0.13 cm to 1.58 cm and 32 to 1458 with means of 2.47 cm, 0.66 cm and 610, respectively (Table 4). Thus, it is possible to improve eggplant cultivars with respect to these traits by direct selection.

Table 4. Mean and range performance of characters among the eggplant accessions

Character	Mean value	Minimum value	Maximum value
LL (cm)	17.10	11.17	21.13
LW (cm)	13.85	4.51	19.65
LP	2.25	0.00	19.96
PL (cm)	6.34	1.79	11.34
PH (cm)	43.99	20.13	60.53
SG (mm)	0.73	0.27	1.00
PB	11.23	8.44	17.78
DF (1st)	100.8	42.30	153.3
DF (50%)	105.9	48.30	154.7
FL (cm)	5.24	1.12	12.82
FB (cm)	4.03	0.90	8.43
FL/FB	1.38	0.83	4.29
FPL (cm)	2.47	0.70	5.00
FPT (cm)	0.66	0.13	1.58
FCP	1.59	0.00	32.40
FPP	0.54	0.00	11.20
NL/F	5.19	1.00	10.60
RFCL (cm)	34.09	15.16	72.04
NF/P	55.50	2.67	248.40
FW/P (g)	219.70	32.10	638.60
FY/plant (kg/ha)	423.10	59.69	1170
NS/F	610.20	32.70	1860
SS (cm)	0.26	0.17	0.37
SW (g)	0.29	0.10	1.10

LL – leaf length, LW – leaf width, LP – leaf prickle, PL – petiole length, FL – fruit length, FB – fruit breadth, FPL – fruit pedicle length, FPT – fruit pedicle thickness, FCP – fruit calyx prickles, FPP – fruit pedicel prickles, NL/F – number of locules/fruit, RFCL – relative fruit calyx length, NF/P – number of fruit/ plant, FW/P – fruit weight/plant, FY/P – fruit yield/plant, NS/F – number of seeds/ fruit, PB – plant branching, PH – plant height at flowering, SG – stem girth, DF (1st) – days to first flowering, DF (50%) – days to 50% flowering, SS – seed size and SW-100 seed weight.

Estimate of variance components

The estimate of phenotypic variance (PV), genotypic variance (GV), phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) are presented in Table 5. The highest phenotypic and genotypic variance was observed for number of seeds/fruit with values 171 145.3 and 161 654.25, respectively, followed by number of fruits/plant with phenotypic variance of 5428.70 and genotypic variance of 86 323.8 (Table 5). The lowest phenotypic and genotypic variance was recorded for seed size with the values of 0.004 and 0.002, respectively (Table 5). Similarly, fruit weight/plant exhibited highest values for PCV (895.37%) and GCV (880.46%), followed by number of seeds/fruit and fruit yield/plant with 529.69% and 5.4.77% and; 370.58% and 270.77% for PCV and GCV, respectively (Table 5).

Deshmukh et al. (1986) reported that, PCV and GCV values higher than 20% are considered as high and values between 10% and 20% are medium, while values less than 10% are considered low. In this regard, high values observed for plant height, days to first flower opening, days to 50% flower opening, fruit calyx prickles, number of fruits/plant, fruit weight/plant, fruit yield/plant and number of seeds/fruit is an indication of the presence of significant variation for these traits and the possibility of effective selection or breeding using these traits. However, moderate variation recorded for fruit pedicel length and relative fruit calyx length (Table 5), suggested that the breeder would have to conduct vigorous selection for the improvement of these traits. While in the case of low values for fruit length and breadth ratio, fruit pedicel thickness, seed size and seed weight, sourcing for high variability would make improvement.

In general, values recorded for PCV was higher compared to their respective GCV values for all traits, which signifies that environmental interaction influenced the expression of these traits, though, the difference observed between PCV and GCV did not differ much in their magnitude which implies that these characters are influenced to a much extent by both environmental and genetic effects. The results are in consonance with Mili et al. (2014) for single fruit weight, seed yield/fruit, fruit yield/plant, fruits/plant; Munniappan et al. (2010) for number of fruits/plant, fruit yield/plant; Sheryl & Shanthi (2009) for fruit length, number of fruits/plant,

Table 5. Estimation of variance components and genetic parameters for 24 characters of eggplant

Characters	CV, %	GV	PV	PCV (%)	GCV (%)	h^2b (%)	GA	GAM, %
LL	8.2	59.12	13.63	89.29	58.79	43.36	4.26	24.95
LW	30.6	61.07	12.74	95.90	66.40	47.93	4.33	31.31
LP	27.0	32.03	94.71	205.17	119.32	33.82	3.14	139.60
PL	11.4	37.49	5.80575	95.69	76.90	64.58	3.39	53.60
PH	6.9	112.93	122.14	166.63	160.23	92.46	18.65	42.39
SG	9.2	0.35	0.37	22.68	22.16	95.46	0.33	45.53
PB	9.3	50..08	73.01	80.63	66.78	68.60	3.92	34.97
DF $^{(1st)}$	2.6	522.32	583.65	240.62	227.63	89.49	40.10	39.79
DF$^{(50\%)}$	3.9	492.42	544.78	226.81	215.63	90.38	38.94	36.77
FL	10.0	101.00	114.13	147.58	138.84	88.49	5.57	106.44
FB	12.7	45.79	68.50	130.38	106.59	66.84	3.75	93.19
FL/FB	18.8	2.72	3.36	49.37	44.43	80.97	0.91	66.37
FPL	12.5	16.21	27.07	104.70	81.01	59.87	2.23	90.46
FPT	16.3	1.45	1.55	48.61	46.95	93.26	0.66	101.42
FCP	19.1	42.38	42.49	5.169	5.163	99.74	11.42	718.63
FPP	32.3	47.17	57.55	326.46	295.57	81.96	3.81	705.89
NL/F	85.3	56.90	61.78	109.10	104.71	92.11	4.18	80.66
RFCL	17.1	21.70	32.68	30.96	25.23	66.40	2.58	7.58
NF/P	34.9	86323.8	542870	312.75	183.22	34.32	2395.57	4316.35
FW/P	19.5	17031.65	17613.15	895.37	880.46	96.69	229.03	104.24
FY/P	19.5	31094	58243	370.58	270.77	53.38	309.46	7.29
NS/F	16.6	161654.25	171145.3	529.67	514.77	94.45	705.61	11.56
SS	17.2	0.0027623	0.004279	12.82	10.30	64.54	0.09	35.47
SW	9.1	0.03674	0.09246	56.46	35.59	39.73	0.33	115.99

LL – leaf length, LW – leaf width, LP – leaf prickle, PL – petiole length, FL – fruit length, FB – fruit breadth, FPL – fruit pedicle length, FPT – fruit pedicle thickness, FCP – fruit calyx prickles, FPP – fruit pedicel prickles, NL/F – number of locules/fruit, RFCL – relative fruit calyx length, NF/P – number of fruit/plant, FW/P – fruit weight/plant, FY/P – fruit yield/plant, NS/F – number of seeds/ fruit, PB – plant branching, PH – plant height at flowering, SG – stem girth, DF (1st) – days to first flowering, DF (50%) – days to 50% flowering, SS – seed size and SW – 100 seed weight.

fruit weight and fruit yield/plant. However, Kumar et al. (2012) and Sharma & Swaroop (2000) reported on low GCV for days to first flowering in eggplant, which is in contrast with the present finding. This could be due to differences in genetic materials used.

Heritability and genetic advance

The estimate of heritability in the broad sense ranged from 99.74% for fruit calyx prickles to 33.82% for leaf prickles (Table 5). Singh, (2001), reported that heritability estimates greater than 80% are considered very high, values between 60 to 79% are moderately high, values ranging from 40 to 59 are medium while values lower than 40% are considered to be low. In line with this, very high heritability was recorded for plant height, stem girth, days to first flower opening, days to 50% flower opening, fruit length, fruit length and breadth ratio, fruit pedicel thickness, fruit pedicel prickles, number of locules/fruit, fruit weight/plant and number of seeds/fruit (Table 5). Moderate heritability was observed for petiole length, plant branching, fruit breadth and relative fruit calyx length and seed size while other characters showed low heritability (Table 5).

Characters showing high heritability suggest that, selection for these traits can be fairly easy for the breeder because there is relatively small contribution of environmental factors and high additive effect to the phenotype. Whereas the low heritability observed for leaf prickles, number of fruits/plant and seed weight indicates a larger environmental influence to the phenotype. Thus, selection may be considerably difficult or impracticable due to the masking effect of the environment. These results corroborates with the findings of Milli et al. (2014), for fruit yield/plant, plant height, seed yield/fruit, fruit weight and fruits/plant and; Muniappan et al. (2010) for fruit length and fruit breadth.

Although, heritability (broad sense) estimate gives an idea about the proportion of observed variability, which is attributed to genetic difference, it does not indicate the amount of genetic improvement that may be obtained from the selection of an individual genotype (Syafrudin et al., 2016; Usman et al., 2014). Genetic advance under selection refers to the improvement of characters in genotypic value for the new population compared with the base population under one cycle of selection at a given selection intensity (Singh, 2001). Thus, the combination of both heritability and genetic advance would be effective and reliable in predicting the response to selection (Singh, 2001). In this study, genetic advance varied from 0.33 for seed weight to 2395.75 for number of fruits/plant while genetic advance over mean (GAM) ranged from 7.29% for fruit yield/plant to 4316.35 for number of fruits/plant (Table 5). High heritability and genetic advance over mean (>60%) was recorded for fruit length, fruit breadth, fruit length and breadth ratio, fruit pedicel thickness, fruit pedicel and calyx prickles, number of locules/fruit and fruit weight/plant. Thus, selection among the accessions may result in significant improvement of these characters. This is in accordance with findings of Chaudhary & Kumar (2014) and Koundinya et al. (2017) in eggplant. Moreover, moderate estimates of heritability and genetic advance for plant height and stem girth showed the presence of non-additive gene action for these characters and consequently, improvement of these characters by selection would be slow. Days to first and 50% flower opening and plant branching exhibited high heritability and low genetic advance which suggested the role of non-additive gene action that include dominance and epistasis.

Conclusion

In this study, significant variations were observed among all characters indicating the scope for selection among the 33 eggplant accessions. The high PCV and GCV values for plant height, days to first flower opening, days to 50% flower opening, fruit calyx prickles, number of fruits/plant, fruit weight/plant, fruit yield/plant and number of seeds/fruit suggest that these characters could be used as selection criteria for eggplant improvement. PCV and GCV values were observed to close for most characters, thus the expression of these characters are influenced by both environmental and genetic effects. Nonetheless, the high values of heritability coupled with genetic advance for characters, such as fruit length, fruit breadth, fruit length and breadth ratio, fruit pedicel thickness, fruit pedicel and calyx prickles, number of locus/fruit and fruit weight/plant indicates the predominance of additive gene effect and thus, selection would be effective through the improvement of these characters.

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