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Stability for descriptors of *Solanum aethiopicum* Shum group (family Solanaceae)

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Solanum aethiopicum **Shum group is a nutrient-rich and income-generating crop enterprise in various sub-Saharan Africa countries. Despite its importance, the development of its improved varieties has not been prioritized. Until now, no field-based descriptor development reference for the crop is available for testing candidate varieties for distinctiveness, uniformity and stability. The purpose of this study is to identify morphological variables that provide identity of *S. aethiopicum* Shum group accessions across environments. With ten accessions across three test locations, it was observed that the highly polymorphic morphological variables were majorly vegetative and a few reproductive ones. They include plant height at flowering, plant canopy breadth, plant branching, petiole color, petiole length, leaf blade length, leaf blade width, leaf lobbing, leaf tip angle, flowering time, style length, fruit position, fruit flesh density, fruits per inflorescence and fruit flavor. A static stability analysis, a common selection technique for obtaining consistence in performance of genotypes, showed that accessions varied in their interaction with environments for different descriptors. The most statically stable accessions were 184P and 163P while the least stables were 168P, 148, 141, and 137. The findings indicate the potential for identifying unique and stable varieties of *S. aethiopicum* Shum group for the processing of official release to farmers.**

Key words: Polymorphic morphological markers; static stability coefficient; field characterization; *Solanum aethiopicum* Shum; genotype by environment interaction.

INTRODUCTION

Shum is one the four recognized morphological groups of the African eggplant (Abukutsa-Onyango et al., 2010; Adeniji et al., 2012; Horna and Gruere, 2006). It is desired for its nutrient-rich leaves (Bisamaza and Banadda, 2017; Ebert, 2014; Ojiewo et al. 2013; Pincus, 2015; Rubaihayo et al., 2003).

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The rest of its groups are Gilo, Kumba and Aculeatum, and they are cultivated for other purposes (Adeniji et al., 2012; Prohens et al., 2013; Sakhanokho et al., 2014; Sękara et al., 2007). All the four groups are diploid (2n = 24) and they are indigenous to Africa (Prohens et al., 2013; Sakhanokho et al., 2014). The diversity for the Shum group of African eggplant (*Solanum aethiopicum*) is believed to be richest in Uganda, owing to favorable agroecologies and the contribution of the leafy vegetable to household diets and incomes (Cernansky, 2015; Ojiewo et al., 2013; Omulo, 2016; Rubaihayo et al., 2003; Ssekabembe, 2008; Ssekabembe et al., 2003; Stone et al., 2011). Elsewhere, the crop receives commercial attention in countries like Cameroon, Burkina Faso, Ghana, Nigeria, India and Brazil (Abbiw, 1997; Bationo-Kando et al., 2015; Gramazio et al., 2016; Kouassi et al., 2014; Ojiewo et al., 2013; Osei et al., 2010; Rémi et al., 2005).

There is an increasing interest among researchers and policy makers in promoting variety development, cultivation, value-addition and consumption of vegetables (Bisamaza and Banadda, 2017; Cernansky, 2015; Ebert, 2014; FAO, 2005; Pincus, 2015; Rubaihayo et al., 2003; Stone et al., 2011). The breeding and exploitation of new varieties is an avenue that can contribute significantly to improving rural income and overall economic development especially in the third world. For instance, development of new varieties with higher yields increases the value and marketability of crops. New varieties should however, meet the distinctiveness, uniformity and stability (DUS) tests as criteria used by national variety release systems (Mendes de Paula et al., 2014; UPOV, 2002). Distinctness describes the extent to which a descriptor can demonstrate differences between varieties; uniformity, on the other hand, describes the level of homogeneity within a variety. Stability of a genotype refers to its tendency to conserve performance across environments (Becker and Leon, 1988; Kamidi, 2001). Plant morphological characters are universally accepted descriptors for DUS testing and varietal characterization of crop species and are useful for distinguishing different varieties. Determining whether descriptors comply with the above mentioned prerequisites can best be done by evaluation of characteristics in field trials in which various genotypes are grown under identical conditions.

Coefficients of stability are used to identify the genotypes exhibiting same performance for specific variables (Balestre et al., 2009; Eberhart and Russell, 1966; Finlay and Wilkinson, 1963; Temesgen et al., 2015). Stability coefficients are commonly used with yield estimates but the same principle can be extended to morphological descriptors (Mendes de Paula et al., 2014; Sabaghnia et al., 2012; Temesgen et al., 2015). Performance stability refers to a genotype's ability to perform consistently, whether at high or low levels, across a wide range of environments. Most stability measures relate to either of two contrasting concepts of stability: "static" and "dynamic" (Eberhart and Russell, 1966; Finlay and Wilkinson, 1963; Lin and Binns, 1988). Static stability is analogous to the biological concept of homeostasis: a stable genotype tends to maintain a constant performance for a particular variable across environments (Lin and Binns, 1988; Palanog et al., 2015). This study aims at identifying: variables that provide identity of Shum accessions across environments, and accessions that are stable in morphological traits. The study generated results on reliable descriptors for field characterization of *S*. *aethiopicum* Shum group genotypes. The study accessions had earlier been characterized under screen house conditions (Sseremba et al., 2017) but needed field verification.

MATERIALS AND METHODS

Testing sites and germplasm

Three evaluation sites in Uganda were used; Ntawo village in Mukono Municipality in the Central region. Ntawo is an on-station field testing site for the Department of Agricultural and Biological Sciences, Uganda Christian University, Mukono. Butiki village in Jinja Municipality was used (near East), and Busamaga village in Mbale Municipality (Far East) in Eastern Uganda. Mukono, Jinja and Mbale are located at about 24, 70 and 230 km, respectively, East of Kampala.

The study accessions were obtained from farming households in Uganda through a field survey in 2014/2015, followed by on-station seed increase and purification by self-pollination. The accessions were assigned codes; some with stem color suffices such as G and P for green and purple, respectively, whenever more than one accession from same survey location possessed similar other attributes other than stem color. Ten accessions were used in this study: 108, 137, 141, 145, 148, 163P, 168P, 183P, 184G and 184P, and they have been described earlier under screen house conditions (Sseremba et al., 2017).

Experimental design

A randomized complete block design (RCBD) with three replications was used at each of the three test sites; Jinja, Mbale and Mukono. The evaluation was carried out during the first rainy season (February to June 2016). Four-row plots of length 4 m were used at an inter-row spacing of 30 cm. Direct sowing into the experimental field was used. The within-row sowing was done by drilling followed by thinning to 10 cm at 4-leaf stage (1 month after sowing). The testing fields were prepared by hand hoeing and use of Glyphosate to reduce on the weeds burden before the germination of planted seed. At planting, D.A.P fertilizer at a rate of 50 kg/acre was applied. Topdressing with N.P.K (25:5:5) was carried after thinning and at 2 months after sowing. Hand weeding within established fields was used.

Data collection

Data were collected during the opening of first flower until physiological ripening of fruit stages, depending on the variable. Forty one morphological variables were measured according to Adeniji et al. (2013) and Sseremba et al. (2017), with some modifications. A brief description of the various variables measured is included in Table 1.

Table 1. Description of variables measured to characterize *Solanum aethiopicum* Shum accessions.

S/N	Variable	Scale/units
1	Plant growth habit (PGH)	3-upright; 5-intermediate; 7-prostrate
2	Stem ridging (STR)	0-absent; 3=shallow; 5-intermediate; 7-prominent
3	Spines on stem (SOS)	0-absent; 3-short; 5-intermediate; 7-long
4	Stem pubescence (SPU)	0-absent; 1-few; 2-intermediate; 3-many; 4-very many
5	Plant height at flowering (PHF)	1-very short(<20); 3-short(~30); 5-intermediate(~60); 7-tall(~100); 9-very tall
6	Plant canopy breadth (PCB)	1-very narrow(<30); 2-narrow(~40); 5-intermediate; 7-broad(~90); 9-very strong(>130)
7	Plant branching (PB)	Number of primary branches per plant
8	Petiole color (PC)	1-green; 2-greenish-violet; 3-violet; 7-dark violet; 9-dark brown
9	Petiole length (PL)	Measured in centimeters (cm)
10	Leaf blade length (LBL)	Measured in centimeters (cm)
11	Leaf blade width (LBW)	Measured in centimeters (cm)
12	Leaf blade lobbing (LL)	1-very weak; 3-weak; 5-intermediate; 7-strong; 9-very strong
13	Leaf tip angle (LTA)	1-very acute(<15°); 3-acute(~45°); 5-intermediate(~75°); 7-obtuse(~110°); 9-very obtuse (~160°)
14	Leaf blade color (LBC)	1-light green; 3-green; 5-dark green; 7-greenish violet; 9-violet
15	Leaf prickles (LPR)	1-very few (1-2); 3-few (3-5); 5-intermediate (6-10); 7-many (11-20); 9-very many (>20)
16	Flowering time (FLW)	Number of days from sowing till first flower opening
17	Stamen length (STL)	Measured in centimeters (cm)
18	Petal length (PEL)	Measured in centimeters (cm)
19	Sepal length (SEL)	Measured in centimeters (cm)
20	Corolla color (COC)	1-greenish white; 3-white; 5-pale violet; 7-light violet
21	Relative style length (RSL)	Measured in centimeters (cm)
22	Pollen production (POP)	0-none; 3-low; 5-medium; 7-high
23	Style exsertion (STE)	3-inserted; 5-intermediate; 7-exerted
24	Fruit length (FRL)	Measured in centimeters (cm)
25	Fruit breadth (FRB)	Measured in centimeters (cm)
26	Fruit length / breadth ratio (FLBR)	Ratio of fruit length to fruit breadth
27	Fruit curvature (FRC)	1-none (fruit straight); 3- slightly curved; 5-curved; 7-snake shaped; 8-sickleshaped; 9-U shaped
28	Fruit shape (FRS)	3-about 1/4 way from the base to tip; 5-about 1/2 way from base to tip; 7-aboit 3/4 way from base to tip
29	Fruit apex shape (FAS)	3- protruded; 5-rounded; 7-depressed
30	Fruit color at commercial ripeness (FCCR)	1-green; 2-milk white; 3-deep yellow; 4-fire red; 5-scarlet red; 6-lilac gray; 7-purple; 8-purple black; 9-black
31	Fruit color distribution at commercial ripeness (FCDC)	1-uniform; 3-mottled; 5-netted; 7-striped
32	Fruit color at physiological ripeness (FCPR)	1-green; 2-deep yellow; 3-yellow-orange; 4-deep orange; 5-fire red; 6-poppy red; 7-scarlet red; 8-light brown; 9-brown
33	Fruit position (FPO)	1-erect; 3-semierect; 5-horizontal; 7-semipedant; 9-pedant
34	Fruit calyx length (FCL)	Measured in centimeters (cm)

Table 1. Description of variables measured to characterize *Solanum aethiopicum* Shum accessions.

35	Fruit cross section (FCS)	1-circular, no grooves; 3-elliptic, no grooves; 5-few grooves (~4); 7-many grooves (~8); 9-very irregular
36	Locules per fruit (LPF)	Number of locules per fruit (N=10)
37	Fruit flesh density (FFD)	1-very loose (Spongy); 3-loose (Crumbly); 5-average density; 7-dense; 9-very dense
38	Fruits per inflorescence (FRPI)	Number of fruits per inflorescence
39	Fruit flavor (FFL)	3-bitter; 5-intermediate; 7-sweet
40	Varietal mixture condition (VMC)	0-pure; 3-slight mixture; 5-medium mixture, 7-serious mixture
41	Flesh browning (FBR)	1 = Immediate browning 0 ~ 1 minute; 2- > 1 ~ 3 minute; 3- > 3 ~ 5 minute; 4-> 5 ~ 7 minute; 5-> 7 ~ 9 minute; 6-> 9 ~ 12 minute; 7-> 12 ~ 15 minute; 8-> 15 ~ 20 minute; 9-> 20 ~ 30 minute; 10 = > 30 minutes

Data analysis

A restricted (residual/reduced) maximum likelihood analysis considering accession and location as factors was implemented in *BreedingView* statistical software (VSN International Ltd, Hemel Office). A boxplot of each of the 41 variables measured was generated from mean values of each accession per location. Presence of spread (or absence of it) in the boxplot was used as criteria for distinguishing variables as either monomorphic or polymorphic. A variable was identified as monomorphic when all accessions had the same mean performance across test locations (Jinja, Mbale and Mukono). It was considered as slightly polymorphic when at least one of the test sites produced similar traits of a character (variable) for all accessions. Highly polymorphic variables (or descriptors) are ones clearly spread (large variation) among accessions at each of the three test locations. A static stability analysis (Finlay and Wilkinson, 1963; Lin and Binns, 1988; Palanog et al., 2015) was then carried out in *Breeding View* on variables which were qualified as highly polymorphic. Coefficients of static stability were used to select the most and least stable accessions per descriptor.

RESULTS

Variables that distinguished study accessions

Based on spread in means of study accessions for measured traits, some variables were monomorphic while the rest were polymorphic. Out of the 41 variables measured, nine were monomorphic although an analysis of variance (ANOVA) revealed detectable variation (Tables 2 to 4). The monomorphic variables namely plant growth habit (PGH), spines on stem (SOS), stem pubescence (SPU), leaf blade color (LBC), leaf prickles (LPR), fruit curvature (FRC), fruit shape (FRS), fruit color distribution at commercial ripeness (FCDC) and varietal mixture condition (VMC) are shown in Figure 1.

A graphical display of some of the monomorphic descriptors is shown in Figure 2. Some variables which were shown as monomorphic using boxplots were confirmed through the ANOVA as non-significant among accessions (Tables 2 to 4). The remaining 32 variables were generally polymorphic. They include stem ridging (STR), plant height at flowering (PHF), plant canopy breadth (PCB), plant branching (PB), petiole color (PC), petiole length (PL), leaf blade length (LBL), leaf blade width (LBW), leaf blade lobbing (LL), leaf tip angle (LTA), flowering time (FLW), stamen length (STL), petal length (PEL), sepal length (SEL), corolla color (COC) and relative style length (RSL). Others include pollen production (POP), style exsertion (STE), fruit length (FRL), fruit breadth (FRB), fruit length / breadth ratio (FLBR), fruit apex shape (FAS), fruit color at commercial ripeness (FCCR), Fruit color at physiological ripeness (FCPR), fruit position (FPO), fruit calyx length (FCL), fruit cross section (FCS), locules per fruit (LPF), fruit flesh density (FFD), fruits per inflorescence (FRPI), fruit flavor (FFL) and flesh browning (FBR).

Of the 32 generally polymorphic variables, 17 were only slightly polymorphic. Those that exhibited slight polymorphism include STR, PEL, SEL, COC, RSL, POP, STE, FRL, FRB, FLBR, FAS, FCCR, FCPR, FCL, FCS, LPF and FBR. A graphic display for some of the slightly polymorphic descriptors is shown in Figure 3. The variables that were highly polymorphic include PHF, PCB, PB, PC, PL, LBL, LBW, LL, LTA, FLW, STL, FPO, FFD, FRPI and FFL. Some of the highly polymorphic descriptors are shown in Figure 4. The 15 variables that exhibited high polymorphism are the only ones which were considered in the analysis of accession stability across environments.

Static stability of accessions across test locations

The static stability represents consistence in

Table 2. Mean squares of measured variables to characterize *Solanum aethiopicum* Shum accessions (part 1 of 3).

Source	d.f	COC	FAS	FBR	FCCR	FCDC	FCL	FCPR	FCS	FFD	FFL	FLBR	FLW	FPO	FRB
Location (LOC)	2	55.116***	2.009***	34.903***	9.339***	1.072***	0.054	16.350***	16.523***	24.523***	0.578	2.226	3502.550***	7.119*	1.314***
Accession (ACC)	15	1.664	1.807***	78.706***	6.418***	0.368***	9.844***	3.610***	28.945***	39.291***	5.515***	1.860***	298.850***	41.182***	15.772***
LOC x ACC	22	1.549	0.717***	5.361***	3.243***	0.309***	0.217***	2.570***	1.883***	6.768***	3.416***	1.672***	108.090***	8.643***	0.170***
Error	332	1.549	0.171	0.526	0.896	0.096	0.062	0.932	0.827	1.072	0.638	0.685	27.42	1.857	0.066

*, ** and *** significance at 5, 1 and 0.1% error allowed, respectively. COC, corolla color; FAS, fruit apex shape; FBR, flesh browning; FCCR, fruit color at commercial ripeness; FCDC, fruit color distribution at commercial ripeness; FCL, fruit calyx length; FCPR, fruit color at physiological ripeness; FCS, fruit cross section; FFD, fruit flesh density; FFL, fruit flavor; FLBR, fruit length / breadth ratio; FLW, flowering time; FPO, fruit position; FRB, fruit breadth.

Table 3. Mean squares of measured variables (part 2 of 3).

Source	d.f	FRC	FRL	FRPI	FRS	LBC	LBL	LBW	LL	LPF	LPR	LTA	PB	PC	PCB
Location (LOC)	2	0.025	0.637***	7.322	0.414**	5.500***	232.184***	87.137***	22.311***	0.038	0.000	68.185***	792.984***	0.484	6758.720***
Accession (ACC)	15	0.042*	8.900***	30.387***	1.277***	2.219***	15.540***	7.045**	22.903***	0.172***	0.000	15.509***	78.514***	23.324***	250.210***
LOC x ACC	22	0.028	0.048	5.758*	0.268***	3.452***	21.279***	12.725***	9.019***	0.093*	0.000	6.159***	32.956***	2.025***	424.190***
Error	332	0.021	0.039	3.624	0.084	0.069	4.193	2.986	2.176	0.056	0.000	1.22	5.464	0.453	57.760

*, ** and *** significance at 5, 1 and 0.1% error allowed, respectively. FRC, fruit curvature; FRL, fruit length; FRPI, fruits per inflorescence; FRS, fruit shape; LBC, leaf blade color; LBL, leaf blade length; LBW, leaf blade width; LL, leaf blade lobbing; LPF, locules per fruit; LPR, leaf prickles; LTA, leaf tip angle; PB, plant branching; PC, petiole color; PCB, plant canopy breadth.

Table 4. Mean squares of measured variables to characterize *Solanum aethiopicum* Shum accessions (part 3 of 3).

Source	d.f	PEL	PGH	PHF	PL	POP	RSL	SEL	SOS	SPU	STE	STL	STR	VMC
Location (LOC)	2	0.063*	0.313**	28867.4***	4.196*	138.157***	0.546	0.972***	0.451***	0.451*	53.497***	0.265***	131.315***	2.191***
Accession (ACC)	15	1.659***	0.362***	1419.3***	9.833***	6.855***	1.613***	1.570***	0.488***	0.297***	5.208***	0.102***	7.535***	3.757***
LOC x ACC	22	0.722***	0.372***	660*0***	3.287***	2.283***	1.180***	0.185***	0.446***	0.355***	3.018***	0.017***	8.672***	1.701***
Error	332	0.013	0.058	117.2	1.156	0.190	0.216	0.005	0.067	0.007	0.460	0.004	0.623	0.097

*, ** and *** significance at 5, 1 and 0.1% error allowed, respectively. PEL, petiole length; PGH, plant growth habit; PHF, plant height at flowering; PL, petiole length; POP, pollen production; RSL, relative style length; SEL, sepal length; SOS, spines on stem; SPU, stem pubescence; STE, style exsertion; STL, stamen length; STR, stem ridging; VMC, varietal mixture condition.

expression of particular morphological traits across the three locations: Jinja, Mbale and Mukono. Accessions 163, 141, 145, 141 (and 145 and 148), 163P, 184P, 184P, 108, 163P, 148, 184P, 184P, 184G, 108 and 168P had the best stability for PHF, PCB, PB, PC, PL, LBL, LBW, LL, LTA, FLW, STL, FPO, FFD, FRPI and FFL, respectively (Table 5). Accession 184P was most frequent for high static stability followed by 163P. The least stable accessions were 168P, 168P, 163P, 108, 148, 141, 141, 168P, 148, 141, 148, 137, 137, 183P and 137 for PHF, PCB, PB, PC, PL, LBL, LBW, LL, LTA, FLW, STL, FPO, FFD, FRPI and FFL, respectively. Accessions 168P, 148, 141, and 137 featured most frequently for

Figure 1. Varietal mixture of *Solanum aethiopicum* Shum.

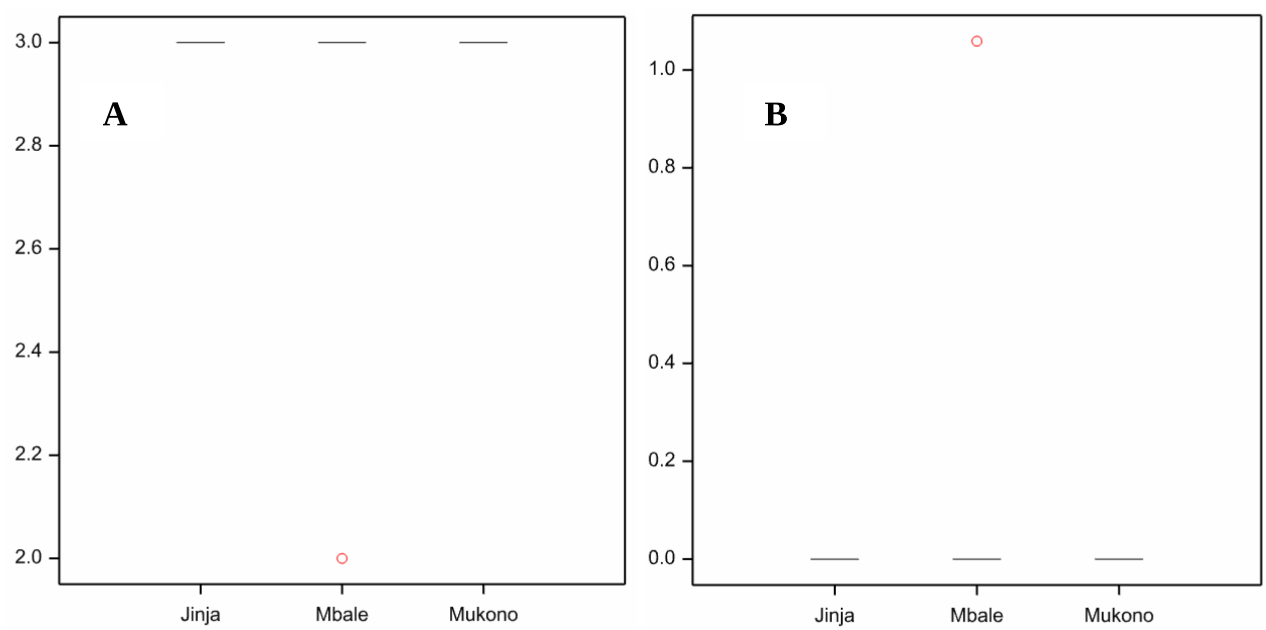

Figure 2. Performance of *S. aethiopicum* Shum accessions at different test locations showing monomorphism for plant growth habit (**A**) and spines on stem (**B**).

least static stability (thrice each).

DISCUSSION

It was observed that some of the variables had same form (or monomorphic) among accessions across test environments. The monomorphic variables are not useful markers for discriminating among genotypes (Odong et al., 2011; Prohens et al., 2013; Sseremba et al., 2017; Sseremba et al., 2018a). The variables namely plant growth habit, spines on stem, stem pubescence, leaf blade color, leaf prickles, fruit curvature, fruit shape, fruit color distribution at commercial ripeness, and varietal mixture condition, cannot be used as descriptors for purposes of identifying distinctiveness among the study accessions. If such monomorphic markers were the only available morphological descriptors, it would necessitate application of deoxyribonucleic acid (DNA) markers which are known for high discriminative power (Gramazio et al.,

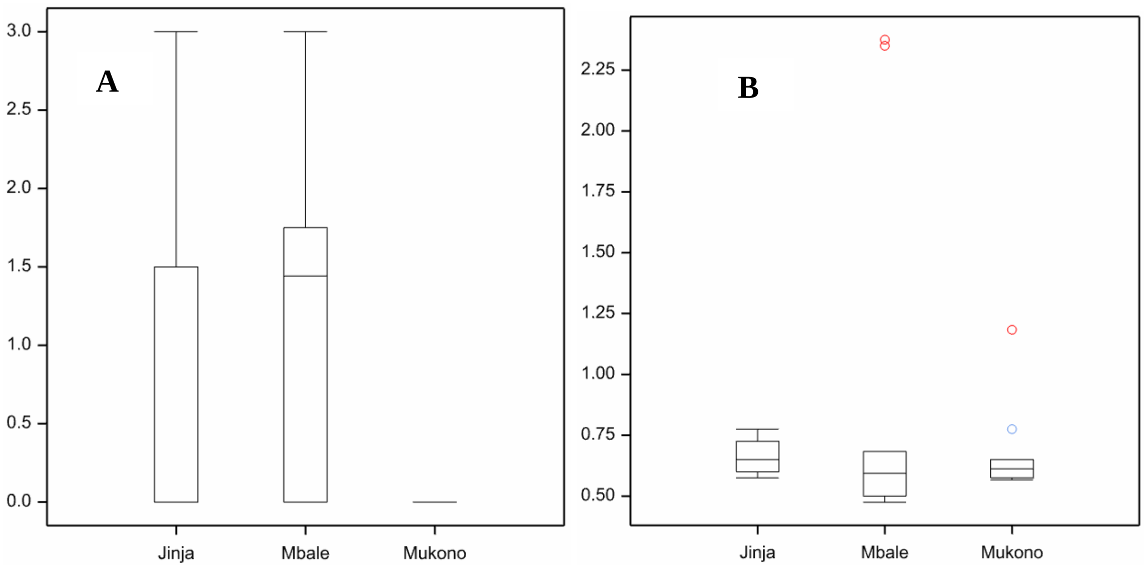

Figure 3. Performance of *S. aethiopicum* Shum accessions at different test locations showing slight polymorphism for stem ridging (**A**) and petal length (**B**).

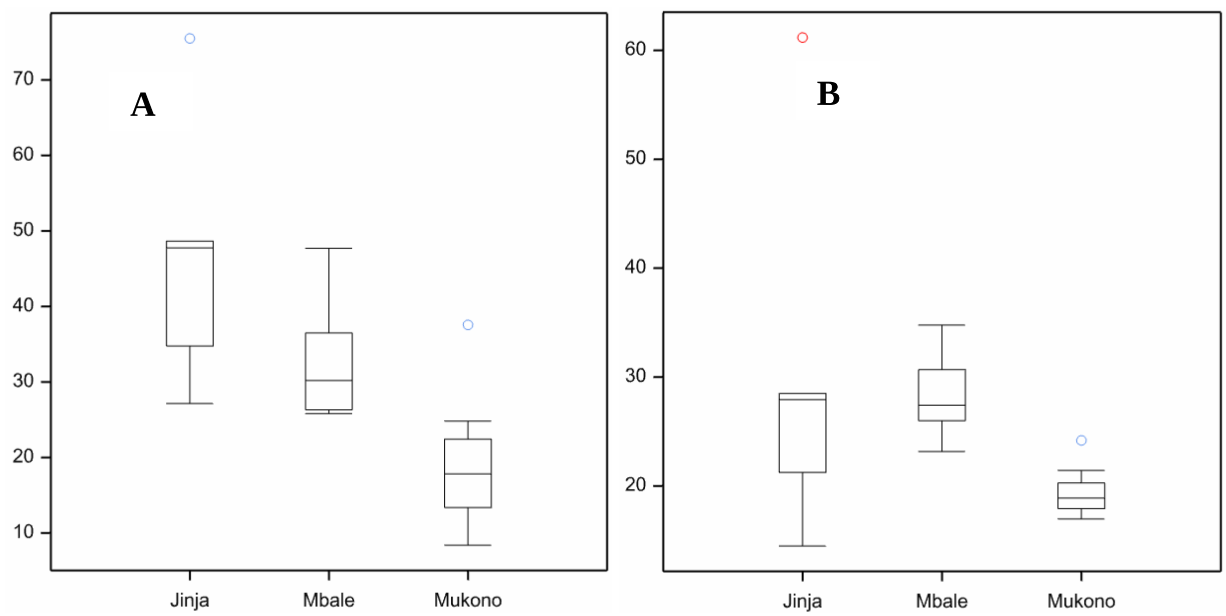

Figure 4. Performance of *S. aethiopicum* Shum accessions at different test locations showing high polymorphism for plant height at flowering (**A**) and plant canopy breadth (**B**).

2016). The DNA markers are however, very expensive particularly for crops such as the *S. aethiopicum* whose information on genomic resources is still scanty. Nonetheless, other morphological variables showed discriminative ability (of varying degrees) among the study accessions. Of the seventeen slightly polymorphic variables, only one (that is, stem ridging) was vegetative. The majority of slightly polymorphic variables were reproductive (flower or fruit related), suggesting a low discriminating power for reproductive structures. Similarly, nine (60%) out of fifteen highly polymorphic variables were vegetative, indicating a high discerning power for vegetative structures of *S. aethiopicum* Shum group (Adeniji et al., 2012).

The highly polymorphic vegetative variables were plant height at flowering, plant canopy breadth, plant

Table 5. Static stability coefficients for highly polymorphic descriptors measured to characterize *Solanum aethiopicum* Shum accessions.

ACC	PHF		PCB		PB		PC		PL		LBL		LBW		LL		LTA		FLW		STL		FPO		FFD		FRPI		FFL	
	Stability	Mean (cm)	Stability	Mean (cm)	Stability	Mean (#)	Stability	Mean (score)	Stability	Mean (cm)	Stability	Mean (cm)	Stability	Mean (cm)	Stability	Mean (score)	Stability	Mean (score)	Stability	Mean (days)	Stability	Mean (cm)	Stability	Mean (score)	Stability	Mean (score)	Stability	Mean (cm)	Stability	Mean (score)
108	200.3	32.5	23.5	24.6	16.5	8	0.5	3	0.2	2.9	1.0	9.1	0.5	7.0	0.1	5	0.4	5	79.1	55.6	0.00	0.37	3.0	6	5.3	6	0.1	4.2	0.0	3
137	276.1	29.6	32.9	24.6	7.2	9	0.0	2	0.1	2.7	2.1	8.2	0.6	6.4	1.7	6	0.2	4	7.0	54.0	0.00	0.42	3.4	7	5.4	4	0.9	4.5	3.7	3
141	192.3	24.1	2.2	21.6	4.8	6	0.0	1	0.0	1.1	12.0	10.2	4.6	7.2	1.2	6	1.2	5	120.6	60.8	0.00	0.62	1.3	8	5.3	6	0.1	4.3	1.3	4
145	78.2	21.7	33.9	19.7	0.2	4	0.0	1	0.5	1.8	4.6	9.2	2.8	6.7	0.6	4	3.7	5	33.6	67.1	0.02	0.55	0.5	8	4.8	6	0.6	4.8	0.5	5
148	198.8	35.2	15.0	28.0	12.8	5	0.0	1	0.8	2.6	8.1	8.6	3.9	6.9	2.3	4	4.4	6	0.4	54.7	0.02	0.51	2.6	6	3.0	6	1.7	2.3	0.3	3
163P	76.6	39.2	20.9	25.5	19.1	9	0.3	2	0.0	2.6	2.8	8.4	1.7	6.3	0.2	4	0.0	4	110.7	57.1	0.00	0.38	3.3	8	4.6	5	0.1	2.8	0.4	4
168P	656.2	48.0	508.9	35.6	2.9	9	0.3	2	0.4	2.9	1.8	9.8	1.6	6.9	2.8	5	1.3	4	41.4	57.1	0.00	0.38	1.0	7	1.8	5	0.3	4.2	0.1	4
183P	278.7	29.4	28.4	23.4	14.9	8	0.0	2	0.4	2.6	1.4	9.1	0.5	6.7	0.5	5	0.1	5	14.9	60.7	0.00	0.42	2.9	6	5.3	6	5.4	2.6	1.0	4
184G	172.1	35.2	22.7	26.7	4.4	9	0.3	1	0.5	3.4	0.5	9.1	0.3	7.1	1.4	6	0.7	5	38.2	55.1	0.00	0.43	3.1	6	0.3	4	0.2	3.4	0.0	4
184P	295.9	31.1	108.5	22.8	10.7	7	0.2	2	0.4	2.9	0.4	8.0	0.2	6.0	0.3	6	0.4	4	18.2	56.9	0.00	0.39	0.1	8	2.8	5	0.1	3.7	0.0	4

ACC, accession. Accessions with smaller static stability values are more stable. PHF, plant height at flowering (cm); PCB, plant canopy breadth (cm); PB, plant branching (#, number of primary branches); PC, petiole color; PL, petiole length (cm); LBL, leaf blade length (cm); LBW, leaf blade width (cm); LL, leaf lobbing (score 1-9); LTA, leaf tip angle; FLW, flowering date (days); STL, stamen length (cm); FPO, fruit position (score 1-9); FFD, fruit flesh density (score 1-9); FRPI, fruits per inflorescence (#); FFL, fruit flavor (score 3-7).

branching, petiole color, petiole length, leaf blade length, leaf blade width, leaf lobbing and leaf tip angle while reproductive ones were flowering time, style length, fruit position, fruit flesh density, fruits per inflorescence and fruit flavor. This observation generally agrees with a previous study in the screen house (Sseremba et al., 2017) but slightly deviates from the work of Adeniji *et al*. (2012) and Prohens et al. (2013). This study and that of Adeniji et al. (2012) were both field-based except the focus was on the leafy (Shum) and all the four recognized morphological groups of *S*. *aethiopicum*, respectively. Sseremba et al. (2017) compared the morphological attributes of *S*. *aethiopicum* and its progenitor, *S*. *anguivi* under screen house conditions; and it was observed that both vegetative and reproductive variates are useful in distinguishing between accessions of the two species. It is notable that *S*. *aethiopicum* Shum is leafy-type while its progenitor is fruit-type (Sękara et al., 2007; Sseremba et al., 2017). This study's observation that almost all the slightly polymorphic variables were reproductive characters suggests that leafy-type species should be described using vegetative structures (for morphological characterization).

From the static stability results, generally, different accessions showed higher stability for some than the rest of the variables. Accessions with the highest number of variables for best static stability were 184P followed by 163P. Conversely, accessions 168P, 148, 141, and 137 had the highest number of variables for least static stability. The observations suggest that either the parameters measured were at different fixation levels (level of homozygosity of same loci) in different accessions or there is a mere difference in form that a variable exhibits in relation to genotype and environment. The possibility of different fixation levels at same loci across accessions can be eliminated on grounds that *S*. *aethiopicum* is a predominantly self-pollinating species (Sakhanokho et al., 2014; Sękara et al., 2007); and pure line accessions were used in this study. Therefore, the effect of cross-pollination on genetic variability is ruled out. It is believed that some accessions were environmentally more robust than others on the account of their innate differences in genotype by environment interaction attributes (Donoso-Ñanculao et al., 2016; Kamidi, 2001; Sabaghnia et al., 2012; Temesgen et al., 2015). Thus, accessions 184P and 163P can be considered as the most stable across test environments while 168P, 148, 141, and 137 were the most sensitive. Sseremba et al. (2018b) had earlier obtained similar results when the environments were based on drought stress levels in a screen house study.

Conclusion

The study aims at firstly, identifying variables that provide identity of Shum accessions across environments, and secondly, identifying accessions that are stable in morphological traits. From the first objective, it was observed that plant height at flowering, plant canopy breadth, plant branching, petiole color, petiole length, leaf blade length, leaf blade width, leaf lobbing, leaf tip angle, flowering time, style length, fruit position, fruit flesh density, fruits per inflorescence and fruit flavor are effective in distinguishing among Shum group accessions of *S. aethiopicum*. In the second objective, it was observed that accessions 184P and 163P were the most statically stable across test environments while 168P, 148, 141, and 137 were the least robust in conserving their morphological traits. A further study on static stability of Shum group genotypes that considers a more diverse source of accessions and additional testing environments is recommended so as to broaden the scope of inference for polymorphic descriptors of the subspecies. A combined use of molecular and morphological markers on same accessions is also recommended for further study; as it could play a cross-check role in attributing the observed morphological differences.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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