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Response of African eggplants to *Fusarium* spp. and identification of sources of resistance

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Eggplant (*Solanum* spp.) production in Arumeru district and other parts of Africa is severely affected by wilting diseases of unknown etiology. *Fusarium* spp. characterized through morphological and sequence analysis of the translation elongation factor associated with Fusarium wilt of eggplants was used to test the response of three different eggplant species. Three *Solanum* spp. accessions were tested in a screen house at the seedling stage for resistance to two isolates each of *Fusarium equiseti* (corda) Sacc*, Fusarium solani* (Mart.) Sacc and *Fusarium oxysporum* (Schlecht). The study indicated that accessions MM 1131 (*Solanum macrocapon)* and N 19 (*Solanum anguivi*) accessions are susceptible to *F. equiseti.* Accession N 19 *(S. anguivi*) was susceptible to *F. solani* while both N 19 *(S. anguivi*) *and* MM 1131 (*S. macrocarpon*) was also susceptible to *F. oxysporum f. sp. melongenae.* Ninety-three accessions of cultivated and wild eggplants were subsequently evaluated in two screen house trials for resistance to *Fusarium* wilt. A root dip technique was used to inoculate the accessions with isolate Fs 40 (*F. oxysporum* f.sp. melongenae)*.* Seventeen of the 93 accessions were found to be resistant and they belonged to *Solanum macrocarpon and Solanum aethiopicum* species. Accessions in *S melongena* were found to be the most susceptible. Eggplant accessions that showed high levels of resistance could potentially serve as valuable sources of *Fusarium* wilt resistance in eggplant breeding programs in Tanzania and beyond.

Key words: African eggplants, *Fusarium* spp. susceptibility, resistance.

INTRODUCTION

Eggplant (*Solanum* spp.) is a multi-species, diploid and seed propagated crop that is cultivated widely in sub-saharan Africa. African eggplant (*S. aethiopicum* L.*)* and *S. macrocarpon* L. are the most popular native traditional

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Table 1. Description, source, morphology, molecular identification and pathogenicity of the Fusaria from wilting eggplants (*Solanum* spp.) that were used in this study.

Isolate code	Host	Site	Collection (2009)	Morphology identification	Differential test
FS 3	*S. macrocarpon*	WVC	July	*F. lacertarum* *	**+**
FS 22	*S. anguivi*	WVC	August	*F. solani*	**+**
FS 24	*S. melongena*	Shangarai	August	F. oxyporum*	**+**
FS 27	*S. aethiopicum gr.Kumba*	AVRDC	July	*F. equiseti* *	+
FS 35	*S. anguivi*	WVC	July	*F. solani**	+
FS 40	*S. melongena*	Shangalai	August	*F. oxysporum* *	+

Identification followed by an * were isolates confirmed by analysis of the ITS region and the α - elongation factor; + Isolate tested of it's pathogenicity; WVC-ARUSHA: World Vegetable Center-ARUSHA.

vegetables in West, and Central Africa. The African eggplant is widely cultivated as a major source of food and is a rich source of vitamins, fibers and minerals. It is also cultivated for medicinal purposes in some countries of Africa (Shippers, 2002) Losses in eggplant production in Africa due to wilt diseases have not been statistically evaluated. Previous research has shown that Fusarium wilt and Verticillium wilt pathogens are the major causal agents of wilting in eggplants (Kouassi et al., 2014).

The search for sources of resistance to Fusarium wilt pathogens has been done using the wild relatives of *S. melongena* and two genes carrying wilt resistance have been tagged (Mutlu et al., 2008; Toppino et al., 2008). *S. anguivi* and *S. aethiopicum* have been utilized in breeding programmes for development of disease resistant eggplant varieties (Altinok et al., 2014; Toppino et al., 2008). Several eggplant accessions have also been utilized in the development and production of disease resistant rootstocks for grafting high yielding varieties (Boyaci et al., 2011; Yoshida et al*.,* 2004).

Two eggplant accessions of *S. aethiopicum* gr. Gilo and *S. aethiopicum* gr. Aculeatum *(Solanum integrifolium*) are known to carry a gene for resistance designated as *Rfo-sa1,* to the fungal wilt disease caused by *F. oxysporum* f. sp. *melongenae* (Toppino et al., 2008). Work done by Altinok et al. (2014) and Iwamoto and Ezura (2006) showed that the high diversity of eggplant germplasm represents a valuable source of wilt resistance genes that could be introgressed into cultivated varieties. The objective of this study was to investigate the differential response of a limited number of African eggplant (*Solanum* spp.) accessions to a range of Fusarium isolates and to search for sources of resistance to the most virulent isolate.

MATERIALS AND METHODS

Differential response of African eggplants (*Solanum spp.*) to inoculation with isolates of *Fusarium* spp*.*

Six isolates of *Fusarium* spp. Coded Fs 24 (1480 JQ244840), Fs 3(1474 JQ244844), Fs 35 (1477 JQ244847), Fs 27(1481 JQ244856), Fs 40(1479 JQ244846), Fs 22 were used in this test. The numbers in parenthesis are accession numbers of the isolates nucleotide sequences deposited in the NCBI genebank. They were isolated from eggplants showing wilting symptoms collected from farmers fields in Arumeru district, AVRDC-RCA eggplant research field (Table 1). Morphological, cultural and molecular characterizations were carried out to confirm the identity of the isolates (Ghoneem et al., 2009; O'Donnell et al., 2009; Seifert, 1996).

Three accessions of *Solanum* spp., SIVONKWE (*S. aethiopicum* gr.Gilo), N 19 (*S. anguivi*), and MM 1131 (*S. macrocarpon*) were used in this study. Inoculation was done on seedlings at the six leaf stage (Altnolk, 2005). The seedlings were lifted gently from the trays and the soil washed off. The root tip of each seedling was cut to two thirds in length. The roots were immersed for 3 min in a suspension of 1×10^6 conidia per ml of *F. oxysporum* f. sp. *melongenae* harvested from 14 day old cultures grown on PDA at 25°C. The control plants were inoculated with distilled sterile water. The seedlings were planted in 15 cm diameter plastic pots containing sterile soil (forest soil mixed with sand at the ratio of 3:1) and placed in a screen house. The experiment was set up in a randomized complete block design with five replicates.

Identification of sources of resistance to eggplant wilt *(Fusarium oxysporum f.sp. melongenae)*

One isolate of *F. oxysporum* f.sp. melongenae coded Fs 40 isolated from infected plants of cultivated aubergine (*S. melongena*) was used. This isolate was used due to its high mean disease index in the differential response test and its high prevalence in the cultivated eggplants (*S. melongena*).

Preparation of inoculum

Single spore cultures were grown on PDA, for consistent sporulation and pigmentation, Petri plates were kept 40 cm below cool white fluorescent tubes and illuminated for 12 h periods at alternating 25°C day/20°C night cycles. Conidia was harvested from 14 day old cultures grown on Potato Dextrose Agar (PDA) at 25°C by adding sterile water to the plates and scraping the surface of the culture with a sterile glass slide. The resulting conidial suspension was filtered through two layers of cheesecloth to remove mycelia fragments. Spore concentrations were then determined using a hemacytometer and adjusted in distilled water to a concentration of 1×10^6 conidia per ml which was adopted in the two trials. The inoculum was used to inoculate seedlings in the susceptibility test.

Susceptibility test

Evaluation for wilt resistance was done according to Yoshiteru et al.

(1996) with modifications. Ninety three eggplant accessions (Table 2) of *S. macrocarpon, S. aethiopicum*, *S. anguivi*, *S. dasyphyllum* and *S. melongena* were inoculated at 5-week-old stage (2-3 true leaves emerged) using root dip inoculation technique. Six seedlings of each accession were planted in 15 cm diameter plastic pots containing sterile soil. The soil was drenched with 5 ml of inoculum ($1x10^6$spores/ml) of *F. oxysporum* f.sp melongenae and the seedlings grown in a screen house. The experiment was laid out in a randomized complete block design with three replicates.

Disease evaluation and statistical analysis

Differential response of the eggplants to the isolates

Plants were monitored daily for wilt development and symptomology and the extent of disease severity recorded at intervals of four weeks starting from the 4th week Scoring was done on a 1 to 5 disease scale where 1 = no symptoms; 2 = slight wilting and yellowing of the lowest leaves; 3 = half of the leaves wilted or showing yellowing; 4 = almost all the leaves wilted or showed yellowing; and 5 = all the leaves wilted, showed yellowing or plant died. The response for each accession and cultivar was determined against a mean disease index calculated according to the following formula (Matsubara et al*.,* 2004):

$$= \frac{\sum(\text{Number of plants} \times \text{degree of symptom})}{\text{Total number of plants} \times 5}$$

Susceptibility test for wilt resistance

The response for each accession and cultivar was determined against a percentage disease index calculated according to the following formula (Matsubara et al*.,* 2004).

$$\text{Disease index} = \frac{\sum(\text{number of plants} \times \text{degree of symptom})}{\text{Total number of plants} \times 5} = \times 100$$

Less than 20% = symptomless; 20 - 40% = slight wilting and yellowing of the lowest leaves; 40 - 60% = almost all the leaves wilted or showing yellowing; 60 - 80% = almost all the leaves wilted or showing yellowing and 80 - 100% all the leaves wilted, showing yellowing or plant died. R: Resistant (< 40%); PR: Partially resistant (40 - 50%); S: Susceptible (>50).

Statistical analysis

Data was analyzed for significant differences using ANOVA and comparison of means among accessions was done using Tukeys HSD. Co STAT statistical package (COHORT Software, Minneapolis, USA) was used to analyze the data. The level of probability was set at P=0.05. Means on the same column followed by a common letter are not significantly different according to the Tukeys test (p≤0.05).

RESULTS

Differential response of African eggplants (*Solanum* spp.) to inoculation with isolates of *Fusarium* spp.

Typical symptoms of eggplant Fusarium wilt were observed when seedlings of MM 1131 and N 19 (susceptible lines) were inoculated with isolates *F. oxysporum, F. solani* and *F. equiseti*. Symptoms on the inoculated seedlings included sudden drooping of leaflets starting from the apical part and progressing downward, yellowing of the leaves which began from one side of the leaf and final wilting of the whole plant. These symptom developments were also observed by Beladid et al. (2004). Complete death of the susceptible seedlings occurred during the 5th week.

The differential tests indicated that isolate Fs 27 (*F. equiseti)* and Fs 24, 40 (*F. oxysporum* f.sp melongenae) generally resulted to a higher mean disease index (>2.5) across the three accessions used compared to the other isolates which had a disease index of < 2.0 (Table 3). *Fusarium equiseti* and *F. oxysporum* were pathogenic to both MM 1131 (*S. macrocapon)* and N19 (*S. anguivi)*. *Solanum anguivi* was susceptible to all the Fusarium isolates except *F. laceratum*. *Solanum aethiopicum* gr. Gilo, (accession Sivonkwe) showed significant resistance to all the isolates except Fs27. Fs 3 was nonpathogenic to any of the *Solanum* spp (Table 3). Re isolation and culturing of the pathogen from the infected stem tissues on PDA yielded colonies of *F. oxysporum*, *F. solani* and *F. equiseti* inoculated and therefore proved positive for Koch's postulates.

Identification of sources of resistance to eggplant wilt *(Fusarium oxysporum f.sp. melongenae)*

The inoculation method adopted gave good disease incidence in all trials, and provided a useful screening system for resistance to Fusarium wilt. Symptoms started after 7 days of inoculation. There were significant differences between the two trials and this was attributed to the different prevailing weather conditions at the time the two trials were carried out. Temperatures were higher and the condition was dry in the duration the 1st trial was carried out compared to the 2nd trial which was characterized by heavy rains and temperatures as low as 13^{o}C during the nights. The maximum and minimum temperatures in the 1st trial ranged from 21 to 34°C while in the 2nd trial ranged from 13 to 29°C therefore the symptoms were more severe. The two trials showed that the strain used in inoculating the accessions (Fs 40) was virulent to the accessions.

12% of the accessions tested were considered as resistant while 71% were partially resistant and 10% susceptible According to Table 4, MM 1044, MM 11044 and MM 10260 were accessions found to be resistant within the *S. macrocarpon* species. There were also very susceptible accessions found in the *S. macrocarpon* species such as MM 855 and MM 283. This shows a high genetic variability within this species and an assumption on this species being totally susceptible or totally being resistant is ruled out. There were no accessions within

Table 2. List of eggplant species and cultivars tested.

Species	Cultivar	Origin
S. aethiopicum	SOS 1	AVRDC gene bank*
S. aethiopicum	UG-AE-4	Uganda
S. aethiopicum	UG-AE-10	Uganda
S. aethiopicum	UG-AE-21	Uganda
S. aethiopicum	TZSMN 2-8	Tanzania
S. aethiopicum	TZSMN 3-10	Tanzania
S. aethiopicum	TZSMN 75-7	Tanzania
S. aethiopicum	ML-AE-5	Malawi
S. aethiopicum	ML-AE-12	Malawi
S. aethiopicum	DB3	Ghana
S. aethiopicum	Manyire Green	Tanzania
Solanum spp.	Landrace	Tanzania
S. aethiopicum	OAA (089)	Cameroon
S. aethiopicum	Small oval	Tanzania
S. aethiopicum	N20	AVRDC gene bank*
S. aethiopicum	Heart shaped	Tanzania
S. aethiopicum	Sivonkwe	AVRDC gene bank*
S. aethiopicum gr. shum	MM347	Congo
S. aethiopicum	MM01150	AVRDC gene bank*
S. aethiopicum gr. Gilo	MM1371	Tanzania
S. aethiopicum	MM1106	AVRDC gene bank*
S. aethiopicum gr. Aculeatum	MM134	France
S. aethiopicum gr. Aculeatum	MM1474	INDE
S. aethiopicum gr. Aculeatum	MM1102	Burkina Faso
S. aethiopicum gr. Aculeatum	MM1483	Inconnue
S. aethiopicum gr. Gilo	MM10181	Ghana
S. aethiopicum gr. Gilo	MM803	Gabon
S. aethiopicum gr. Gilo	MM870	Madagascar
S. aethiopicum gr. Gilo	MM1641	Africa(Ouest)
S. aethiopicum gr. Gilo	MM10086	Togo
S. aethiopicum gr. Gilo	MM10245	Zambia
S. aethiopicum gr. Gilo	MM1480	Inconnue
S. aethiopicum gr. Gilo	MM1188	Inconnue
S. aethiopicum gr. Gilo	MM11010	Cote D' Voire
S. aethiopicum gr. Gilo	MM196 TER	Burkina Faso
S. aethiopicum gr. Gilo	MM868	Tchad (Bousso)
S. aethiopicum gr. Gilo	MM458	Japon
S. aethiopicum gr. Gilo	MM10079	Togo
S. aethiopicum gr. Gilo	MM10213	Ghana
S. aethiopicum gr. Gilo	MM1162	Uganda
S. aethiopicum gr. Kumba	MM574	Senegal
S. aethiopicum gr. Kumba	MM1642	Africa(Ouest)
S. aethiopicum gr. Kumba	MM1107	Burkina Faso
S. aethiopicum gr. Kumba	MM1207	Mali
S. aethiopicum gr. Kumba	MM267	Mauritania
S. aethiopicum gr. Shum	MM1121	Zambia
S. aethiopicum gr. Shum	MM1119	Togo
S. aethiopicum gr. Shum	MM1161	Bernin
S. aethiopicum	UG-AE-1	Uganda
S. aethiopicum	UG-AE-3	Uganda
S. aethiopicum	UG-AE-14	Uganda

Table 2. Contd.

S. aethiopicum	UG-AE-15	Uganda
S. aethiopicum	UG-AE-23	Uganda
S. aethiopicum	UG-AE-24	Uganda
S. melongena	Black beauty	Tanzania
S. dasyphyllum	MM1164	Togo
S. dasyphyllum	MM12126	Uganda
S. macrocarpon	MM10256	Ghana
S. macrocarpon	MM714	Zimbabwe
S. macrocarpon	MM10260	Ghana
S. macrocarpon	MM11044	Cote D' Voire
S. macrocarpon	MM132	France
S. macrocarpon	MM1131	Togo
S. macrocarpon	MM 150	Cote D' Voire
S. macrocarpon	MM283	AVRDC gene bank*
S. macrocarpon	MM12209	Zaire
S. macrocarpon	MM252	Ghana
S. macrocarpon	MM855	Togo
S. macrocarpon	UG-AE-6	Uganda
S. macrocarpon	UVPP	Tanzania
S. macrocarpon	CR001	Cameroon
S. macrocarpon	MM01139	AVRDC gene bank*
S. macrocarpon	MM01064	AVRDC gene bank*
S. melongena	S. 00677	AVRDC gene bank*
S. melongena	S. 00718	AVRDC gene bank*
S. melongena	S. 00735	AVRDC gene bank*
S. melongena	S. 00811	AVRDC gene bank*
S. melongena	S. 00017	AVRDC gene bank*
S. melongena	S. 0052	AVRDC gene bank*
S. melongena	S. 00204	AVRDC gene bank*
S. melongena	S. 00256	AVRDC gene bank*
S. melongena	S. 00736	AVRDC gene bank*
S. melongena	S. 00567	AVRDC gene bank*
S.melongena	TS00567	AVRDC gene bank*
S.melongena	TS00131	AVRDC gene bank*
Solanum anguivi	N19	AVRDC gene bank*
S. anguivi	MM1103	Burkina Faso
S. anguivi	MM905	AVRDC gene bank*
S. anguivi	MM159	AVRDC gene bank*
Solanum spp.	TZSMN 15-2	Tanzania
Solanum spp.	ML-AE-4	Malawi
Solanum spp.	ML-AE-6	Malawi
Solanum spp.	ML-AE-9	Malawi

*Germplasm without place of origin data.

the *S. melongena* species categorized as being resistant.. Accesions MM 1161, MM 1616, UG AE– 21, MM 1119 and SOS1 in the *S. aethiopicum* species were resistant to the Fusarium isolate used. This species also exhibited a high genetic variability in its resistance to *F. oxysporum* f.sp. *melongenae* (FOM). Accessions used within the *S. anguivi* and *S. dasyphyllum* species were found to range from partially resistant to susceptible

DISCUSSION

The survival and activity of *Fusarium spp.* is greatly dependant on many factors, with the most important ones being soil moisture, soil and air temperatures (Mui-Yun,

Table 3. Behavior of three African eggplants after inoculation with different isolates of *Fusarium* spp.

Accession code	Mean disease severity (1 - 5);Isolates tested for pathogenicity						
	Fs 24 F.oxy	Fs 35 F.sol	Fs 22 F.sol	Fs 27 F. equi	Fs 3 F. lac	Fs 40 F.oxy	Control
MM 1131	3^{ab}	1.2^{cd}	1.2^{cd}	3^{ab}	1.0^{d}	2.6^{abcd}	1.2^{cd}
N 19	2.8^{abc}	2.6^{abcd}	2.8^{abc}	4^{a}	1.6^{bcd}	2.8^{abc}	1.4^{bcd}
SIVONKWE	1.2^{cd}	1.8^{bcd}	1.4^{bcd}	2.4^{abcd}	1.4^{bcd}	1.4^{bcd}	1.0^{d}

***Values on each column followed by a letter in common are not significantly different at (P ≤ 0.05). Foliar symptom scale (1-5), higher numbers indicate severerity of disease.

Table 4. Reaction of eggplant accessions and cultivars after artificial inoculation with *Fusarium oxysporum* f.sp *melongenae* (FS 40) expressed as disease incidence (%) in the two trials.

Species	Accession code	Trial 1	Trial 2	Average	Tukeys test
S. macrocarpon	MM 10260	36.7	20	28.3^{R}	e
S. aethiopicum	MM 1119	33.3	23.3	28.3^{R}	e
Solanum spp.	UG AE 6	33.3	26.7	30^{R}	e
S. aethiopicum	SOS1	30	33.3	31.7^{R}	e
S. aethiopicum	MM 1616	43.3	20	31.7^{R}	e
Solanum spp.	ML AE 6	40	26.7	33.3^{R}	e
Solanum spp.	ML AE 4	30	40	35^{R}	de
S. aethiopicum	MM 1161	36.7	36.7	36.7^{R}	de
S. macrocarpon	MM 11044	36.7	36.7	36.7^{R}	de
S. aethiopicum	MM 10079	40	33.3	36.7^{R}	de
S. aethiopicum	MM 1207	40	33.3	36.7^{R}	de
S. aethiopicum	UG AE-21	30	43.3	36.7^{R}	de
Solanum spp.	MM 1692	40	36.7	38.3^{R}	de
S. aethiopicum	TZ SMN AE 3-10	50	30	40^{R}	de
S. aethiopicum	MM 11008	36.7	43.3	40^{R}	de
S. macrocarpon	MM 1044	46.7	33.3	40^{R}	de
Solanum spp.	LANDRACE	50	30	40^{R}	de
Solanum spp.	MM 01139	36.7	46.7	41.7^{PR}	de
S. aethiopicum	MM 1160	43.3	40	41.7^{PR}	de
S. aethiopicum	N 20	40	43.3	41.7^{PR}	de
Solanum spp.	ML AE 9 GKK 149	43.3	40	41.7^{PR}	de
Solanum spp.	MM 1498	50	33.3	41.7^{PR}	de
Solanum spp.	SITE 101	40	43.3	41.7^{PR}	de
S. aethiopicum	MM 11010	50	36.7	43.3^{PR}	de
S. aethiopicum	MM 348	50	36.7	43.3^{PR}	de
S. dasyphyllum	MM 12126	46.7	40	43.3^{PR}	de
S. melongena	S 00813	46.7	40	43.3^{PR}	de
Solanum spp.	UG AE-23	40	46.7	43.3^{PR}	de
S. aethiopicum	MM 347	43.3	43.3	43.3^{PR}	de
S. dasyphyllum	MM 1164	43.3	43.3	43.3^{PR}	de
S. macrocarpon	MM 1062	43.3	43.3	43.3^{PR}	de
S. aethiopicum	MM 10086	40	50	45^{PR}	de
S. aethiopicum	MM 1106	43.3	46.7	45^{PR}	de
S. aethiopicum	MM 1107	46.7	43.3	45^{PR}	de
S. aethiopicum	MM 1121	46.7	43.3	45^{PR}	de
S. aethiopicum	MM 1162	50	40	45^{PR}	de
S. aethiopicum	MM 1642	43.3	46.7	45^{PR}	de

Table 4. Contd.

S. aethiopicum	MM 803	46.7	43.3	45^{PR}	de
S. aethiopicum	SMALL OVAL TYPE	50	40	45^{PR}	cde
S. aethiopicum	TZ SMN-AE 2-8	56.7	33.3	45^{PR}	cde
S. aethiopicum	TZ SMN AE 52-3	50	40	45^{PR}	cde
S. aethiopicum	MM 10252	46.7	43.3	45^{PR}	cde
S. macrocarpon	MM 1048	50	40	45^{PR}	cde
S. macrocarpon	MM 12209	40	50	45^{PR}	cde
S. macrocarpon	MM 132	36.7	53.3	45^{PR}	cde
Solanum spp.	MM 1007	40	50	45^{PR}	cde
S. aethiopicum	MM 10213	46.7	46.7	46.7^{PR}	cde
Solanum spp.	ML AE 5 29-7	46.7	46.7	46.7^{PR}	cde
S. aethiopicum	MM 1102	50	43.3	46.7^{PR}	cde
S. aethiopicum	MM 870	50	43.3	46.7^{PR}	cde
S. anguivi	MM 159	50	43.3	46.7^{PR}	cde
S. melongena	S 00736	50	43.3	46.7^{PR}	cde
Solanum spp.	UG AE- 5	43.3	50	46.7^{PR}	cde
Solanum spp.	UG AE-14	43.3	50	46.7^{PR}	cde
S. aethiopicum	MM 574	50	46.7	48.3^{PR}	cde
S. melongena	OOO17	43.3	53.3	48.3^{PR}	cde
S. melongena	S 00718	43.3	53.3	48.3^{PR}	cde
S. melongena	TZ 00567	30	66.7	48.3^{PR}	cde
Solanum spp.	UG AE - 24	43.3	53.3	48.3^{PR}	cde
S. aethiopicum	MANYIRE GREEN	53.3	46.7	50^{PR}	bcde
S. aethiopicum	MM 10245	60	40	50^{PR}	bcde
S. aethiopicum	UG AE-10	60	40	50^{PR}	bcde
S. aethiopicum	MM 196	46.7	56.7	51.7^{S}	bcde
S. melongena	TS 00131	56.7	46.7	51.7^{S}	bcde
Solanum spp.	MM 138	56.7	46.7	51.7^{S}	bcde
S. aethiopicum	MM 1158	60	46.7	53.3^{S}	bcde
S. melongena	OO 204	46.7	60	53.3^{S}	bcde
S. aethiopicum	MM 868	53.3	53.3	53.3^{S}	bcde
S. aethiopicum	MM 1188	56.7	53.3	55^{S}	bcde
S. aethiopicum	MM 1483	60	50	55^{S}	bcde
S. aethiopicum	MM 1615	50	60	55^{S}	bcde
S. melongena	OO 677	50	60	55^{S}	bcde
S. aethiopicum	MM 1371	56.7	56.7	56.7^{S}	abcde
S. anguivi	MM 905	56.7	56.7	56.7^{S}	abcde
S. macrocarpon	MM 150	56.7	56.7	56.7^{S}	abcde
S. aethiopicum	MM 134	63.3	50	56.7^{S}	abcde
S. aethiopicum	MM 1480	66.7	46.7	56.7^{S}	abcde
S. aethiopicum	TZ SMN AE 75-7	63.3	50	56.7^{S}	abcde
S. melongena	OO 567	60	53.3	56.7^{S}	abcde
S. melongena	S 00735	60	53.3	56.7^{S}	abcde
S. aethiopicum	MM 1474	56.7	60	58.3^{S}	abcde
S. aethiopicum	MM 267	46.7	70	58.3^{S}	abcde
S. macrocarpon	CR 001	56.7	60	58.3^{S}	abcde
S. aethiopicum	MM 10181	63.3	56.7	60^{S}	abcde
S. aethiopicum	DB 3	63.3	56.7	60^{S}	abcde
S. anguivi	MM 1103	60	60	60^{S}	abcde
S. melongena	BLACK BEAUTY	60	60	60^{S}	abcde
S. anguivi	N 19	66.7	63.3	65^{S}	abcd
S. macrocarpon	MM 1131	63.3	66.7	65^{S}	abcd

Table 4. Contd.

S. aethiopicum	MM 1308	66.7	70	68.3^{S}	ab
S. macrocarpon	MM 283	70	76.7	73.3^{S}	ab
S. melongena	OO 256	80	73.3	76.7^{S}	a
S. macrocarpon	MM 855	80	83.3	58.7^{S}	a

Each value is the mean % disease incidence of six plants. Means followed by the same letter are not significantly different following Tukeys test, ($P \leq 0.05$).

2003). The significant differences within the two trials were as a result of the prevailing environmental conditions during the time the two trials were carried out. *F. oxysporum* is a warm weather pathogen and wilting is more prevalent when the temperatures are high (28°C) and in moisture stressed soils. Infected plants may remain symptomless in wet seasons (Lester et al., 1988).This explains the higher disease severity of the accessions in the first trial compared to the second trial. Similar reports indicate that *Fusarium spp.* requires soil and air temperatures of 25 to 28°C (Mui-yun, 2003) to effectively infect their hosts.

Among the isolates used for the pathogenicity test, *F. equiseti* caused the highest wilting in *S. macrocarpon* and *S. anguivi* accessions followed by *F. oxysporum* f.sp melongenae. Pathogenicity of *F. oxysporum* f.sp melongenae to eggplants has also been reported by several authors (Altinok, 2005; Zhuang, 2005; Cho and Shin, 2004)*,* however accession SIVONKWE in the *S. aethiopicum* gr. Gilo proved to be resistant in this case. This study confirms previous work showing accessions of *S. aethiopicum* gr. Gilo to carry resistance to *Fusarium oxysporum* f.sp melongenae though other accessions within the species have also been found to be susceptible (Stravato and Capelli, 2000; Toppino et al., 2008). The resistant Sivonkwe accession can be used in breeding for resistance to *Fusarium* spp. and other wilt related pathogens. *Fusarium equiseti* pathogenicity in eggplants has not been reported and further studies on its economic importance on cultivated eggplants would contribute significantly to wilt control. *Fusarium equiseti* and *F. solani* have been reported to cause heavy wilting and severe seedling root rot in sunflower (Sharfun-nahar and Mushtaq, 2007). The colonization and pathogenicity of *F. equiseti* on tomatoes has also been observed by Jamiołkowska, (2009). It's pathogenicity has been linked to a pathogenic factor known as equisetin and trichothecenes (Hestbjerg et al., 2002; Wheeler et al., 1999).

The screening of the 93 accesions *to F. oxysporum* f.sp melongenae exhibited a whole range of reactions, that is, resistance, partial resistance and susceptible. Accessions within the *Solanum dasyphyllum* species (MM 1164, MM 12126) found to be partially resistant to *F. oxysporum* f.sp melongenae are wild eggplant species which have not been cultivated but these accessions would be valuable if used as rootstocks. *S. macrocarpon* is not susceptible to most diseases and is resistant to damping off caused by *Thielaviopsis basicola* (Shippers, 2002). Certain cultivars of *S. macrocarpon* have been reported to be resistant to *Fusarium* wilt (Grubben and Denton, 2004). Interspecific hybridization between *S. macrocarpon* and *S. melongena* is known to produce fertile hybrids and therefore can be used in transfer of the resistant traits to cultivated eggplants. *Solanum macrocarpon* and *S. dasyphyllum* can also be crossed easily and therefore produce fully fertile hybrids (Shippers, 2002). *Solanum aethiopicum* gr. Gilo accessions exhibited reactions ranging from resistance, partial resistance to susceptibile. Similar results were reported by Stravato and Cappelli (2000). This may be explained by the existence of genetic variability within the *S. aethiopicum* groups Gilo and Shum as reported by Sekara et al. (2007).*Solanum aethiopicum* groups, Shum and Kumba were found to carry a higher resistance than Group Gilo. *Solanum aethiopicum* (MM 1161, MM 1616, UG AE– 21, UG AE-6, SOS1, MM 10079, MM 1207 and MM 11008 and TZSM NAE-3-10) are valuable for breeding for resistance. Further evaluation for resistance to Verticillium and bacterial wilts would be important for eggplant improvement. Accession SOS1 (*S. aethiopicum* gr. *Gilo* X *S. aethiopicum* gr. *Aculeatum)* which was found to be resistant by Toppino et al. (2008) was also resistant in this study. Previous work has reported eggplant (*S. melongena*) to be susceptible to *F. solani* resulting to crown rot, vascular discoloration and wilt (Nabi et al., 2013; Romberg and Davis, 2007; Chakraborty et al., 2008). Consideration of the *Fusarium* spp. causing wilt in *S. anguivi* and *S. macrocarpon* is important when breeding for resistance to wilt for accessions within this species. More screening should also be done to test the resistance of the *S. aethiopicum* species groups to *F. equiseti* and *F. solani.*

Categorizing host reactions (resistant, partially resistant, susceptible) can be useful in indicating an accessions response to disease in disease favourable environments. The present study clearly shows that resistance to fusarium wilt exist in non-commercial eggplant germplasm which can be exploited to reduce losses.

Conflict of interests

The authors have not declared any conflict of interest.

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