Assessment of Sweet Potato (*Ipomoea batatas* Lam.) Viral Diseases and Homopterous Insects in Wolaita Zone, Southern Ethiopia

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Abstract

The study was conducted in sweet potato fields to determine the current distribution of common sweet potato viral diseases and homopterous insect pests in Wolaita zone, Southern Ethiopia. A total of 60 sweet potato fields were examined for incidence and severity of viral diseases. Based on the observations of the symptoms all of the surveyed fields (100%) showed virus-like symptoms due to virus infection or other factors inducing similar responses. For the virus identification, 300 symptomatic and 20 asymptomatic sweet potato samples were collected from farmers' fields of which an average of 38.7% of symptomatic and 25% of the symptomless samples were positive for at least one virus by ELISA test. The most prevalent sweet potato infecting viruses detected throughout the study areas were Sweet potato chlorotic stunt virus (SPCSV), (14.7 to 84 %) Sweet potato feathery mottle virus (SPFMV) (13.3 to 21.3%) and Sweet potato chlorotic fleck virus (SPCFV) (4.5%) in order of their prevalence. Mixed (dual and triple) infections were also common. Incidences of co-infection by SPCSV and SPFMV reached 20% in Damot Galle. Mixed infections by SPCFV+SPCSV and SPCFV+SPCSV+SPFMV were about 13.6% and 31.8%, respectively. Sweep net and pan trap collections of homopterous insects during the vegetative growth of sweet potato crops indicated that Cicadellidae family was the most prevalent followed by family Cercopoidea. Whiteflies were predominant while aphids were absent during the survey periods. A total of 600 symptomatic and 200 asymptomatic sweet potato plants were randomly harvested from farmers' fields at maturity. Significant yield differences were obtained and the average mean weights of tuber yield from symptomatic and symptomless plants were 0.21 kg and 0.65 kg per plant, respectively. The study showed that the incidence and severity of sweet potato viral diseases had a significant positive relation with insect abundance and a significant negative relationship with sweet potato yield. Our study was only from four districts and more studies of a wider scale are recommended on assessments of viruses and vectors on sweet potatoes in different agroecologies in Ethiopia. .

Key words: Co-infection, ELISA, Insect Vectors, *SPCSV, SPCFV, SPFMV*

Introduction

Sweet potato (*Ipomoea batatas* (L.) Lam.) is a member of the *Convolvulaceae* (morning glory) family, originating from South America (Loebenstein and Thottappilly, 2009). It is widely grown worldwide and cultivated throughout the tropical and warm temperate regions wherever there is enough water to support growth (Austin, 1988; Vincent, 2009). Recent reports indicated developing countries contribute around 97% of the sweet potatoes grown worldwide (Sapakhova *et al.*, 2023). Sweet potato is most intensively produced in China and around the Great Lakes of East Africa (Loebenstein and Thottappilly, 2009). It is an important subsistence crop in East Africa (Valkonen *et al.*, 2013). In Ethiopia, it is mainly grown in the South, Southwestern, and Eastern parts of the country where the population density is large and it is one of the most important crops for at least 20 million Ethiopians (Assefa *et al.*, 2007). Recently, it has been distributed to different parts of Ethiopia where natural and man-made disasters prevail, and this action will increase the area of production, yield, and producers of sweet potatoes.

According to Endale *et al.*, (1994), sweet potato is one of the most adaptive food crops in Ethiopia. However, the current productivity of sweet potato in Ethiopia is lower than 6-8 tones/ha, far below the world average of 13.7 tons/ha (Sapakhova *et al.*, 2023), although the country has the potential to produce up to 50-60 tons/ha (Daniel and Gobeze, 2016). This huge variation is attributed to biotic and abiotic factors (Belehu, 2003).

Insect pests and viral infection are the major biotic constraints of sweet potato production (Chavi *et al.*, 1997). Sweet potato infecting viruses are by far the most serious pathogens that cause substantial yield losses in sweet potatoes in the world (CIP, 2000). According to Clark *et al.*, (2012), there are more than 30 viruses known to infect cultivated sweet potato worldwide. These viruses may infect as a single infection or multiple infections. The most devastating yield loss is caused when sweet potato is infected by co-infection of *Sweet potato feathery mottle virus* (SPFMV) and *Sweet potato chlorotic stunt virus* (SPCSV) commonly referred to as Sweet Potato Virus Disease (SPVD). Yield losses of 60–95% that vary depending on the cultivar were reported in Uganda (Adikini *et al.*, 2015). The SPVD shows symptoms that lead to stunted plant growth, low production of roots, leaf narrowing and bend, and chlorosis and it can cause yield reduction of 56-98% in Africa (Gibson *et al.*, 1998).

Virus disease on sweet potato in Ethiopia was first reported over three decades ago and confirmed by electron microscopy examination of sweet potato plants with mosaic symptoms from Nazreth and identified as SPFMV (SPL, 1986). Although

viruses cause devastating diseases to sweet potatoes worldwide, they were not considered important and economic disease in Ethiopia until 2004 (Tameru, 2004, Geleta, 2009; Abraham, 2010). However, since late 2004, virus diseases have been recognized as an important and greatly reduce the yields of sweet potatoes (Geleta, 2009).

More than eight viruses infecting sweet potatoes were detected in Ethiopia (Dereje *et al.,* 2020b) of which SPCSV and SPFMV are the most prevalent. Sweet potato vine propagator farms and research centers were reported to suffer from virus infection (Abraham, 2010; Dereje, 2023). Many authors reported that sweet potato virus diseases are widely distributed in Wolaita zone and are a major problem in the Southern Region of Ethiopia (Tameru, 2004; Tewodros *et al.,* 2011 Tesfaye *et al.,* 2013, Dereje *et al.,* 2020a, Dereje 2023). Studies on sweet potato viral diseases and insect vectors are scanty, and the available information is limited to a few locations. As a result, the extent of the problem is yet to be understood. Besides, the role of insect vectors in virus transmission and their control measures have been studied less. Hence, the current study assessed the importance of sweet potato viruses and homopterous insects in Wolaita zone, Southern Ethiopia.

Materials and Methods

Description of the study sites

This study was conducted from December 2016 to May 2017 in Wolayita zone, Southern Nation, Nationalities, People Region State (SNNPRS), Ethiopia. Four districts in the zone i.e. Boloso Sore, Damot Galle, Humbo and Sodo Zuria (Fig 1) were selected for the study based on the intensity of sweet potato production and accessibility. The elevations of survey areas ranged from 1643 to 1910 m.a.s.l. Depending on the availability, sweet potato farms having a minimum area of 200 m^2 of sweet potato were randomly selected at 3-5 km interval, and data were recorded on the vectors encountered, and symptoms, severity, and incidence of the disease.

Survey of major homopterous pests on sweet potato

A focused survey was conducted on homopterous insects, which are linked to vectoring viral diseases. A total of 60 sweet potato farmers' fields were visited. Insects were sampled using sweep nets and yellow pan traps periodically from each survey area during the vegetative growth stage of the plant. Hundred sweeps were made in a zigzag manner over the field with a sweep net with a diameter of 15 cm.

Yellow water traps (∅26cm X 10cm h) were filled with water and kept on the ground in the middle of a sweet potato field and were emptied and serviced weekly for four weeks. Specimens

were collected and preserved in vials with 70% ethanol, and the specimens were sorted, counted, and identified at a family level with the help of a stereomicroscope and the book Borror and Delong's Introduction to the Study of Insects (Triplehorn and Johnson, 2005) in the Crop Protection Laboratory of Hawassa University. The index of the species diversity was calculated by using the Shannon-Wiener diversity index (1949).

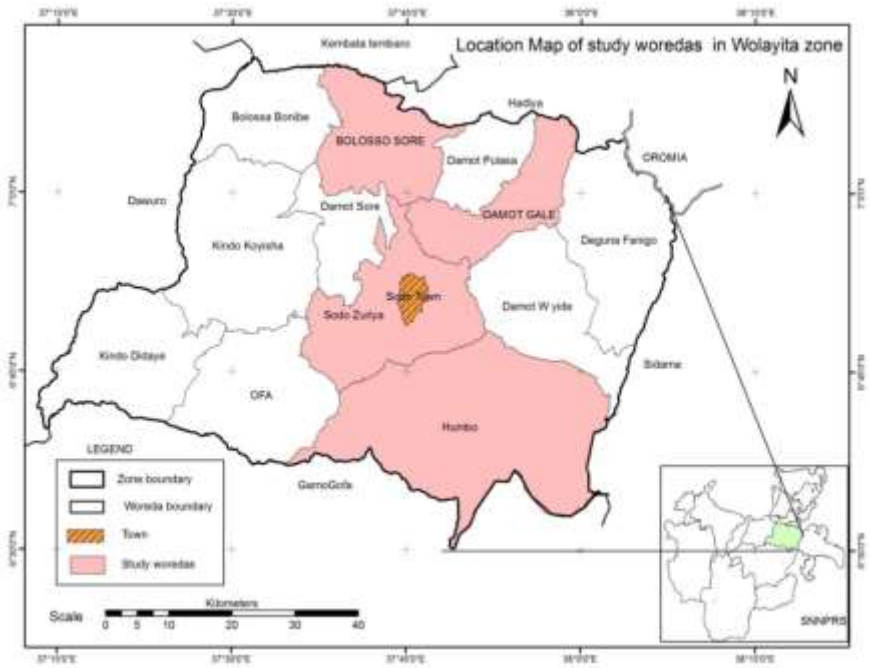

Figure 1. Map of the study area

Assessment of aphids and whiteflies on sweet potato plants

Five sweet potato fields at the vegetative stage (storage root initiation) were selected from each district, and thirty sweet potato plants per field were randomly selected along a diagonal transect in each field. The numbers of aphids and whiteflies were counted on seven apical leaves of each plant and the total numbers of the whiteflies and aphids represented the estimated numbers per plant (Ndunguru *et al.*, 2009).

Survey of viral diseases affecting sweet potato plants

The virus disease survey was conducted on 60 sweet potato fields across four districts (15 fields per district) in Wolayita zone, southern Ethiopia. In each field, 25 plants were examined for viral disease symptoms, and samples were collected from a 1m x 1m quadrant along the diagonal transect line over the field (Feistrizer, 1975). The incidence of virus and virus-like symptoms (X) and incidence of virus infection (Y) were calculated

following the formula proposed by James (1974) as follows:

$$X = \frac{\text{Number of symptomatic samples in a given field}}{Total\ number\ of\ plant\ samples\ in\ the\ field} x\ 100$$

$$Y = \frac{\text{Number of infected sample}}{Total\ number\ of\ test\ samples}\ x\ 100$$

Symptom severity was estimated using a scoring scale of 1-5 where 1 = symptomless and 5 = very severe symptom, and the visual scoring of severity was assisted with color print image of symptomatic plants (Ndunguru *et al.*, 2009). Plants expressing distinct viral symptoms and/or mild to severe symptoms were preferentially sampled for the subsequent virus testing.

Sample collection and virus testing

A total of 320 sweet potato leaf samples (300 symptomatic and 20 asymptomatic) were randomly collected along a diagonal transect across the surveyed 60 fields. The samples were kept in separate paper bags with collection dates, locations, and the sweet potato field labels. Samples were brought to Hawassa University, College of Agriculture laboratory for serological tests.

The presence of six viruses: SPCSV, SPFMV, Sweet potato mild mottle virus (SPMMV), Sweet potato virus 2 (SPV2) and sweet potato chlorotic fleck virus (SPCFV) and Cucumber mosaic virus (CMV) in the sweet potato leaf samples was tested with double antibody sandwich enzyme-linked immune sorbent assay (DAS-ELISA) and triple antibody sandwich enzyme-linked immune sorbent assay (TAS-ELISA) following the protocol developed by Clark and Adams (1977) with certain modifications. The five viruses were tested by DAS-ELISA, except SPCSV, which was tested using TAS ELISA. The virus testing was conducted at the Plant Tissue Culture Laboratory of the College of Agriculture, Hawassa University. Purified Immunoglobulin G (IgG) was diluted in coating buffer at the recommended dilution of 1:1000 proportions, and 100µl of the mixture was added into each well of the ELISA plate and incubated at 37 ^{0}C for 3 hrs. Plates were washed for 3 minutes with phosphate-buffered saline Tween 20 (PBS-T) and blotted by placing them upside down on tissue paper. Approximately 0.5 g of fresh weight of fully expanded sweet potato leaf; from the top, middle, and lower parts of each sweet potato plant, and the sap was extracted in ELISA bag using extraction buffer. Then 100µl of sample sap, positive and negative controls were added to duplicate wells and incubated at 4 ^{0}C overnight. The washing step was repeated three times. Then IgG-AP enzyme-linked antibody was diluted 1:1000 in the conjugate buffer according to the ratio given in

the delivery note and 100µl of enzyme-conjugate antibody was added into duplicate wells and incubated for 3 hrs at 37^0C. In TAS-ELISA, Rabbit anti-mouse alkaline phosphates conjugated (RAM-ap) were mixed with conjugate buffer in 1:1000 proportions, and 100µl was added to each well and incubated for 2 hrs at 37 ^{0}C for further reaction. After washing and blotting, 100µl aliquots of freshly prepared substrate were added and incubated at room temperature for 30-60 minutes. The development of yellow color in the microplate wells was visually assessed and counted as positive. Those that did not develop a yellow color were considered virus-negative/undetected. Norwegian University of Life Sciences, Norway, provided all the ELISA-kits we used for virus detection.

.Impact of viral disease and insect pests on sweet potato yield

A total of 20 sweet potato fields were assessed to evaluate the impact of viral diseases and insect pests on the yield of sweet potato. A total of 40 sweet potato plants (20 symptomatic and 20 symptomless were randomly selected and vines and roots of individual plants were harvested from each selected farmer's field at the maturity stage. Yield per plant was estimated from symptomless and symptomatic sweet potato plant samples in each study district. The number and weight of roots and main branches per plant were recorded accordingly for yield comparison (Tesfaye *et al.*, 2013). All data on virus-like incidences, and symptom severity, were collected by random sampling of farmers' sweet potato fields at 3 km from each other.

Data analysis

All the collected data on disease incidence and severity, and abundance of insects was summarized using descriptive statistics. Data on the yield of sweet potato was subjected to analysis of variance using the least significant difference test at $P < 0.05$ with SAS (version 9.0). The relationship between different variables (disease, insect, and sweet potato yield) was investigated by a bivariate Pearson's correlation analysis.

Results and Discussion

Abundance of Homopterous insect pests in sweet potato fields

A total of 1,123 and 2,078 specimens of homopterous insects belonging to three families were collected from the survey areas using the sweep net and pan trap, respectively. The Cicadellidae family was the most dominant insect on sweet potato, regardless of the collection method. When sweep nets were used for collection, the family Cicadellidae had the highest diversity index of 0.29 at Boloso Sore district, while the lowest, 0.18, was recorded at Damot Galle district. However, the family Cercopoidea showed the lowest diversity index of 0.0079 (Fig. 2).

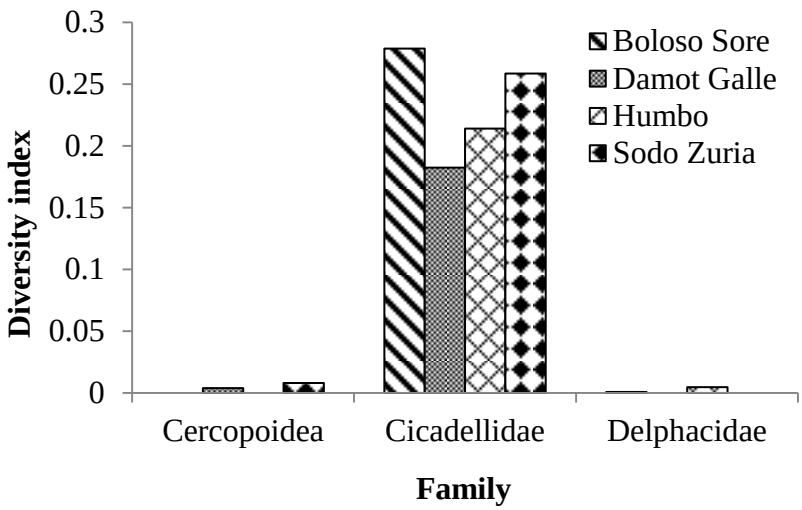

Figure 2. Diversity index of homopterous insects on sweet potato crops in Wolaita zone, Southern Ethiopia

The insects collected with pan traps showed that family Cicadellidae was the most abundant, followed by Cercopoidea (Fig. 3). The population density of Cicadellidae ranged from log 7.48 to 8.45. The number of Cercopoids was high during the first sampling and declined through the subsequent sampling dates. On the other hand, the Delphacidae family was the lowest during all sampling dates (Fig. 3).

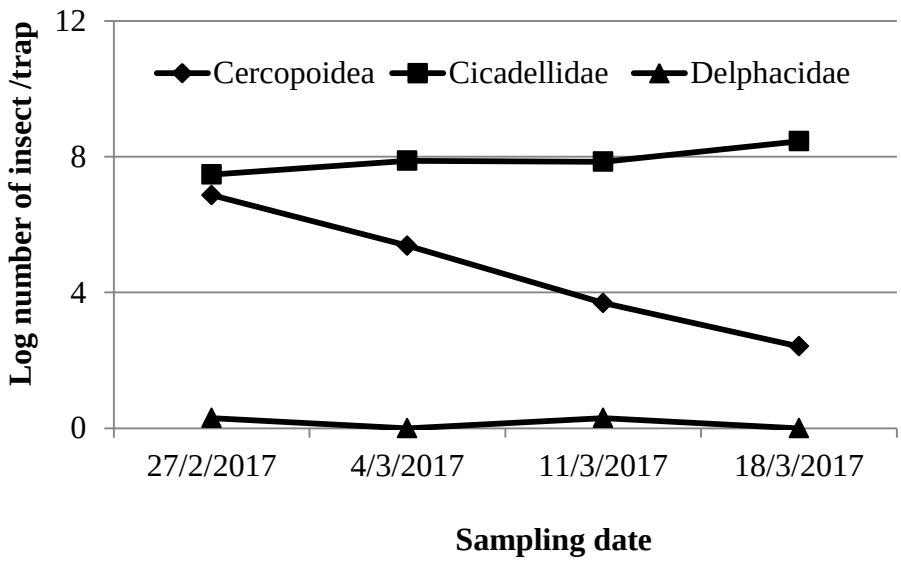

Figure 3. Abundance of homopteran insects on sweet potato in Wolaita zone, Southern Ethiopia.

Viral diseases in sweet potato fields

Symptom description of sweet potato viral diseases

The most observed virus-like symptoms in surveyed districts were general chlorosis, leaf distortion, purpling, stunting, and vein chlorosis (Fig. 4). This agreed with the work of Tewodros *et al.* (2011) and Ndunguru *et al.* (2009), which reported chlorotic spots, mottling, general chlorosis, leaf clearing, leaf distortion, mosaic, purpling, stunting, thinning and vein chlorosis as the most observed symptoms during previous surveys.

Sweet potato plants in Damot Galle district had very severe virus-like symptoms, followed by Sodo Zuria, Boloso Sore and Humbo districts in that order. Plants with general chlorosis, interveinal chlorosis, mottling, purple spots, thinning, stunting, and deformed leaf symptoms indicated for more than two virus infections in the ELISA test, while plants with characteristic symptoms of general chlorosis and purpling were mainly of SPCSV infection.

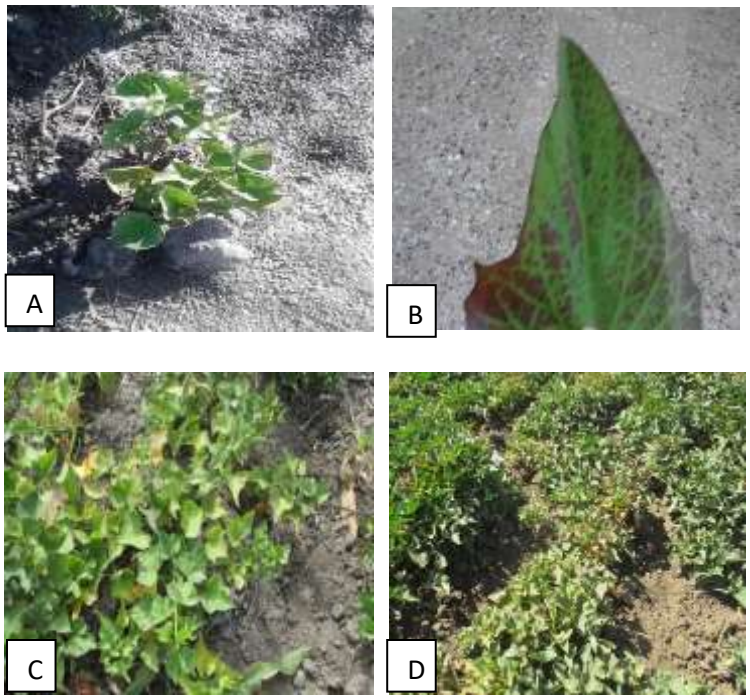

Figure 4. Virus and virus-like symptoms observed on sweet potato field plants in Wolaita zone, Southern Ethiopia. A: Chlorosis, deformed leafs, mottling, thinning and stunting; B: Purple spot and mottling; C: General chlorosis; D: Purpling

Incidences of virus infection

Viruses were detected in all the districts surveyed with frequencies ranging from 4.5% -84% and 0% - 40% in the symptomatic and asymptomatic samples, respectively. Overall, about 38.7% of symptomatic and 25% of asymptomatic samples were positive for one or more viruses. Most of the symptomatic samples (61.3%) did not react to any of the tested antisera, although the symptoms resembled those caused by viruses, suggesting that non-viral pathogens or environmental factors may have caused the observed symptoms. This finding agrees with the findings of Mukasa *et al.* (2003); Ateka *et al.* (2004) and Tairo *et al.* (2004) who have reported that plants exhibiting virus-like disease symptoms in the field can negatively react to antisera. The virus-like symptoms on the tested plant samples could be caused by viruses that have not been tested yet and associated with the plants. It should also be noted that the symptoms observed may be caused by non-viral factors or due to undetectable viral titer (Gibson *et al.*, 1998; Salazar and Fuentes, 2000).

Out of the 300 symptomatic sweet potato plant samples tested by TAS and DAS-ELISA, 116 (38.7%) samples were infected by SPCSV 41 (13.7%) samples showed mild reactions to SPFMV antibody, 25 (8.3%) were co-infected by SPCSV and SPFMV (SPVD), and 7 (4.5%) of 157 symptomatic samples were infected by SPCFV. Of the 20 symptomless plant samples, 4 (20%) and 1 (5%) samples were infected by SPFMV and SPCSV, respectively. Four of the six tested viruses (SPCFV, SPMMV, CMV, and SPV2) were not detected in both symptomatic and asymptomatic sweet potato plant samples from Humbo, Boloso Sore, and Sodo Zuria.

SPCSV is the most prevalent virus detected in all surveyed fields of the Wolaita zone. The same trend was reported by Dereje Haile (2023), who tested samples from selected areas in southern Ethiopia. The possible use of infected planting materials from previous fields, lack of disease-free planting materials, and little or lack of knowledge about virus disease transmission and abundance of whitefly vectors may aggravate SPCSV distribution in study areas. However, the current findings contradict the earlier studies that reported SPFMV as the most widespread viral disease everywhere sweet potato is grown (Tameru, 2004; Tewodros *et al.,* 2011). This might be due to the poor detectability of this virus by ELISA.

The incidence of single and mixed infections of viral diseases varied in each study district. The highest (84%) incidence of single infections of SPCSV was recorded in Damot Galle, followed by Sodo Zuria district (30.7%), and the lowest (14.7%) was in Humbo district. Similarly, the incidence of SPFMV was the highest (21.3%) in Sodo Zuria, followed by Damot Galle (20%), and not detected

(0%) in Humbo district. The incidence of SPCFV infection was 4.5% and occurred only in Damot Galle district. Furthermore, co-infections observed in the current survey included that of SPFMV+SPCSV (SPVD), SPCSV+SPCFV, and SPCSV+ SPFMV+ SPCFV (SPVD + SPCFV). The incidence of SPVD infection in the test samples was the highest (20%) in Damot Galle and the lowest (5.33%) in Boloso Sore district. SPVD caused by dual infections of SPFMV and SPCSV is widespread in most of the study locations. These results agreed with the findings from previous surveys in Ethiopia by Tewodros *et al.* (2011) and Tesfaye *et al.* (2013), who reported co-infections of SPFMV and SPCSV as the most widespread, resulting in severe disease symptoms in sweet potato plants in Ethiopia. A recent report by Dereje (2023) also revealed the same result. A similar finding was reported in Uganda by Mukasa *et al.* (2003). The dual infections of SPCFV + SPCSV and SPCSV + SPFMV (SPVD) were 13.6% and 31.8%, respectively, in Damot Galle district. In the current survey, SPCFV was detected for the first time in sweet potato from Ethiopia with much lower frequency than the other viruses detected in symptomatic samples. The new virus was detected in samples collected from the Damot Galle district as a single, and dual infection with SPCSV and triple infection with SPCSV and SPFMV (SPVD). This limited distribution might indicate the recent introduction of this virus to the farmer's field with new materials. Current results coincide with the work of Kreuze *et al.* (2005), Untiveros *et al.* (2006), and Opiyo *et al.* (2010), who reported SPCFV in symptomatic, multiple infected field plants and mixed infection with SPCSV and SPFMV.

Symptom severity of sweet potato viral diseases and white fly population

The severity of the sweet potato virus disease symptoms varied between surveyed fields. The highest (3±0.04) and lowest (2±0.03) disease severity scores were recorded at Damot Galle district and Humbo district, respectively (Table 1). SPVD-affected plants displayed moderate to very severe symptoms compared to plants infected with individual viruses, suggesting that symptom expression is influenced by the virus species/strain, whether the infection is single or dual, host response, plant age at the time of infection, and temperature (Mukasa *et al.*, 2003; Ndunguru and Kapinga, 2007).

Table 1. Vector population and viral disease severity in Wolaita zone, Southern Ethiopia

Districts	Mean number of white fly/plant ± SE	Mean severity of virus scoring ± SE
Boloso Sore	4.9 ± 0.2	2.2± 0.03
Damot Galle	4.3 ± 0.2	3 ±0.04
Humbo	5.9 ± 0.3	2 ± 0.03
Sodo Zuria	5.1 ± 0.3	2.3 ± 0.04
Mean	5.05 ± 0.1	2.4 ± 0.02

±SE = standard error of the mean

Whiteflies were observed in all surveyed districts. However, aphids were absent during the periods of the survey. The highest (5.9±0.3) mean number of adult whiteflies per plant was recorded in Humbo, while the lowest (4.3±0.2) was in Damot Galle district (Table 1). The result agrees with Ferdu *et al.* (2009) and Tesfaye *et al.* (2013), who reported the prevalence of whiteflies in sweet potato fields in southern Ethiopia.

Sweet potato yield in the surveyed fields

The number and weight of roots and vines per plant of symptomless plants showed a highly significant difference ($p<0.0001$) as compared to that of symptomatic plants in all the studied districts except Humbo (Table 2). The highest mean number and weight of roots and vines per plant were recorded from symptomless plants (Table 2).

The highest mean root number (5.19) and mean root weight (1.00 kg) per plant was recorded from symptomless plant. In contrast, the highest mean root number (2.58) and root weight (0.26 kg) was recorded from symptomatic plants. This result indicate symptomless sweet potato plants gives approximately three times root yield compared to symptomatic plants of same variety.

Similarly, Aritua *et al.* (1998) reported that virus-infected symptomatic plants commonly produce less than half the tuberous root yield of symptomless ones. From symptomatic plants, the lowest (1.4±0.7) and the highest (3.7±1.2) mean numbers of roots per plant were recorded in Sodo Zuria and Damot Galle districts, respectively. The lowest mean weight (0.2 kg/plant ±0.1) of root from symptomatic plants was recorded in Sodo Zuria and Humbo districts, while the highest mean weight (0.26 kg/plant ± 0.1) of root was recorded in Boloso Sore district. However, there was no significant difference among sweet potatoes harvested from the four districts in root yield per plant (Table 2).

The highest (6.6±1.2) and lowest (4.1±0.8) mean numbers of vines per plant (symptomatic plant) were recorded in Humbo and Damot Galle districts, respectively. Similarly, the highest (0.4±0.1) and lowest (0.2±0.1) mean weight (kg/plant) of the vine of symptomatic plants was recorded in Boloso Sore, and Sodo Zuria and Damot Galle districts, respectively. However, differences in the weight of

the vines from symptomatic plants were insignificant between Humbo and Bolos Sore, and between Sodo Zuria and Damot Galle districts (Table 2). Overall, the current study revealed that viral diseases significantly affect the growth and development of sweet potato plants and lower the number and weight of the roots and vines compared to the performance of asymptomatic plants. This result agrees with Tesfaye *et al.* (2013), who reported a considerable effect of SPVD on yield and yield components of sweet potato.

Correlation between sweet potato viral diseases, insect abundance and sweet potato yield

Positive and highly significant ($p \leq 0.01$) correlations were detected among virus disease parameters and insect abundance in Boloso Sore district (Table 3). This indicates that knowledge of the relationship between disease severity and insect abundance in the field is critical to estimating the extent of losses in crop yield.

Table 2. Yield of symptomless and symptomatic sweet potato plants (by viral diseases and insect pests) collected from fields in Wolayta zones southern Ethiopia

District		Number of tuberous roots	Weight of tuberous root/plant(Kg)	Number of vines	Weight of vine/plant (Kg)
Boloso Sore	Symptomless	$5.19^{a} \pm 0.92$	$0.76^{b} \pm 0.11$	$7.75^{a} \pm 1.39$	$0.37^{c} \pm 0.075$
	Symptomatic	$2.58^{e} \pm 0.97$	$0.26^{d} \pm 0.09$	$4.53^{e} \pm 1.43$	$0.19^{d} \pm 0.08$
Damot Galle	Symptomless	$4.76^{b} \pm 0.97$	$0.64^{c} \pm 0.12$	$8.11^{a} \pm 0.95$	$0.45^{b} \pm 0.08$
	Symptomatic	$3.66^{c} \pm 1.15$	$0.25^{d} \pm 0.11$	$6.62^{c} \pm 1.17$	$0.37^{c} \pm 0.09$
Sodo Zuria	Symptomless	$3.09^{d} \pm 0.77$	$1.03^{a} \pm 0.16$	$7.18^{b} \pm 0.99$	$0.84^{a} \pm 0.07$
	Symptomatic	$1.35^{f} \pm 0.70$	$0.16^{f} \pm 0.09$	$5.15^{d} \pm 0.86$	$0.37^{c} \pm 0.09$
Humbo	Symptomless	$2.28^{e} \pm 0.68$	$0.17^{f} \pm 0.09$	$4.10^{e} \pm 0.77$	$0.24^{d} \pm 0.08$
	Symptomatic	$2.27^{e} \pm 0.66$	$0.16^{f} \pm 0.09$	$4.07^{e} \pm 0.82$	$0.23^{d} \pm 0.10$
Mean		3.15	0.43	5.93	0.01
$LSD_{0.05}$		0.24	0.03	0.29	0.02
CV		27.54	27.73	18.09	21.09

± SD- Standard deviation, weight is measured in kg/plant

Means followed by the same letter within a column are not significantly different at P <0.0001.

The observed levels of the diseases and insect pests had a considerable adverse effect on the yield of sweet potato. Viral disease severity showed a strong, significant negative association with sweet potato yield and its components (root number, root weight, and vine weight) ($p \leq 0.01$) and number of vines ($p \leq 0.05$). Also, disease incidence and insect abundance had a significantly negative correlation with sweet potato yield and number of vines per plant ($p \leq 0.05$) and had a highly significant negative correlation with number of roots, weight of roots, and number of vines per plant ($p \leq 0.01$). However, the insect population had a non-significant negative correlation with the number of roots per plant (Table 3a).

Disease incidence, severity, and insect population had a strongly significant negative relation with sweet potato

yield and yield components (number of roots, weight of roots, number and weight of vines) ($p \leq 0.01$), disease incidence had a significant negative relation with the weight of vine ($p \leq 0.05$) (Table 3a). There was a strong, significant positive correlation between viral disease parameters and insect abundance ($p \leq 0.01$) in Damot Gale, whereas viral disease incidence had a significant positive correlation with insect abundance ($p \leq 0.05$). Disease incidence, severity, and insect population had a strong and significant negative relation with sweet potato yield and yield components (number of roots, weight of roots, number and weight of vines) ($p \leq 0.01$), while disease incidence had a significant negative relation with the weight of vines ($p \leq 0.05$) (Table 3a). In support of our findings that the yield of sweet potato was significantly affected by the viral diseases incidence and severity and insect abundance, Gibson *et al.* (1998) reported that sweet potato viral diseases cause large reductions in both foliage and root yield of individual plants and resulted in 50% to more than 90% yield reduction.

Table 3. Relationship of SPVD incidence, severity, insect abundance, sweet potato yield and its components.
. Upper (Boloso Sore) and Lower (Damot Galle) diagonal correlation

Variables	Disease incidence	severity	Insect Abundance	Number of roots/plant	Root Weight /plant(Kg)	Number of vine/plant	Vine weight/plant (g)	Yield/plant (Kg)
Disease Incidence		0.76**	0.81**	-0.78**	-0.85**	-0.62*	-0.87**	-0.57*
Disease Severity	0.85**		0.84**	-0.67**	-0.69**	-0.52*	-0.86**	-0.74**
Insect abundance	0.77*	0.88**		-0.36	-0.71**	-0.64*	-0.69**	-0.54*
Root number	-0.72**	-0.74**	-0.90**		0.45**	0.19	0.49**	0.36**
Root weight	-0.83**	-0.81**	-0.87**	0.49**		0.23*	0.38**	0.38**
Vine number	-0.74**	-0.84**	-0.89**	0.062	-0.03		0.47**	0.42**
Vine weight	-0.54*	-0.53**	-0.84**	0.31**	0.12	0.21*		0.25*
Yield	-0.66**	-0.68**	-0.79**	0.40**	0.28**	0.19*	0.13	

*. Correlation is significant at the 0.05 level.
**. Correlation is significant at the 0.01 level.

b. Upper (Humbo) and Lower (Sodo Zuria) diagonal correlation

Variables	Disea Incidence	Severity	Insect abundance	Number of root /plant	Root Weight/plant (Kg)	Number vine/plant	Vine weight/plant(Kg)	Yield/plant (Kg)
Disease Incidence		0.58*	0.68**	-0.35	-0.63*	-0.45	-0.82**	-0.73**
Disease severity	0.76**		0.64*	-0.41	-0.53*	-0.69**	-0.75**	-0.52*
Insect abundance	0.86**	0.89**		-0.64**	-0.82**	-0.71**	-0.65**	-0.58*
Root number	-0.93**	-0.96**	-0.90**		0.29**	0.22*	0.04	0.47**
Root weight	-0.86**	-0.90**	-0.82**	0.82**		0.05	0.16	0.19
Vine number	-0.69**	-0.73**	-0.37	0.32*	0.36**		0.19	0.53**
Vine weight	-0.63*	-0.65*	-0.24	0.06	0.08	0.60**		0.26**
Yield	-0.94**	-0.93**	-0.82**	0.49**	0.48**	0.29*	0.19	

*. Correlation is significant at the 0.05 level.

**. Correlation is significant at the 0.01 level.

There was a highly significant positive correlation between viral disease incidence and insect abundance ($p \leq 0.01$), while the association between disease severity and insect abundance was significant and positive ($p \leq 0.05$) in Humbo district (Table 3b). Viral disease incidence had a strong, significant negative relation with sweet potato yield and weight of vine per plant ($p \leq 0.01$) and had a significant negative relation with the weight of root. Disease severity had a significant negative correlation with yield and weight of root per plant and a highly significant negative correlation with the number and weight of vines per plant ($p \leq 0.05$, $p \leq 0.01$), respectively. On the other hand, insect abundance had a significant negative correlation with yield and a highly significant negative relation with yield components ($p \leq 0.05$, $p \leq 0.01$). However, a negative and non-significant correlation was observed between disease incidence and both the number of roots and vines per plant, while disease severity also had a non-significant negative correlation with the number of roots ($p > 0.05$) (Table 3b) in Humbo district. Clark *et al.* (2012) suggested that the lowest viral disease incidences of <10% cause much crop loss because the sprawling habit of most cultivars allows for the poor yield of diseased plants to be compensated for by increased yields of neighboring healthy plants.

The incidence of virus and virus-like diseases in Sodo Zuria district had a highly significant positive correlation with disease severity and insect abundance ($p \leq 0.01$) (Table 3b). Also, disease incidence, severity, and insect abundance had a highly significant negative correlation with sweet potato yield and its components (number and weight of root and number of vines) ($p \leq 0.01$) and a significant negative correlation with weight of vines per plant ($p \leq 0.05$).

However, insect abundance had a non-significant negative correlation with the number and weight of vines per plant ($p > 0.05$) (Table 3b). The study showed that viral disease severity and the abundance of insect pests determine the extent of reduction in yield and yield components of the crop. This finding agreed with Aritua *et al.* (2000), Difeo *et al.* (2000), and Mukasa *et al.* (2006), who reported 80% to 90% sweet potato yield loss in virus complex-infected fields, including *Sweet potato chlorotic stunt virus* and other potyviruses. On the other hand, the assessed homopteran insect pests had a significant negative effect on the yield and yield component of the crop. This result coincides with Capinera (2001), who reported that the plant hopper in the order Homoptera, a sap-feeding insect, causes damage known as hopper burn, and feeding results in curling, stunting, yellowing, and eventual browning of the potato foliage, and even low numbers of leafhoppers can cause significant yield losses.

Conclusion

This study showed the status of sweet potato viral diseases, the abundance of whitefly vectors, and the presence and abundance of other homopterous insect pests with the potential to vector viral diseases in sweet potato fields of Wolaita zone. There is a need to identify the species of homopterous insects collected on sweet potatoes and study their efficiency in transmitting viral disease. The newly reported SPCFV should be confirmed using sensitive molecular detection methods. Our study was restricted to four districts in a growing season. Sweet potato is widely cultivated in many regions of the country, and more studies of wider scales are recommended on assessments of viruses and vectors on sweet potato in different agro-ecologies in Ethiopia.

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