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Identification of Weed Hosts of *Tomato yellow leaf curl virus* in Field-Grown Tomato in Sudan Savanna, Nigeria

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ABSTRACT

This study is aimed to detect weed hosts of *Tomato yellow leaf curl virus* (TYLCV) in field-grown tomato (*Solanum lycopersicum* L.) in Sudan savanna regions (Gombe, Jigawa and Kano States) of Nigeria during 2017 and 2018 dry and wet seasons. Three farms each from three Local Government Areas (LGAs) of each State were surveyed. Ten symptomatic and asymptomatic weed samples within and around each farm (n = 1080) were randomly collected and assayed against TYLCV using Triple Antibody Sandwich Enzyme-linked Immunosorbent Assay (TAS-ELISA). Based on the obtained results, 14 weed species from 12 families were detected as alternative host of TYLCV in all States surveyed but with variation in distribution. Gombe and Kano States had significantly ($p \leq 0.05$) the highest number (7) of TYLCV weed hosts while the lowest number (4) of TYLCV weed hosts was recorded in Jigawa State. *Cassia obtusifolia* Linn., significantly ($p \leq 0.05$) showed the highest TYLCV frequency rating of 12.1%. The study reports for the first time 13 weed species naturally occurring as an alternative host of TYLCV in Nigeria. The detection of these weed hosts of TYLCV will give a better understanding of the virus disease epidemiology for its effective management. Exploring more weed hosts of TYLCV and molecular characterization of the virus in these weeds for the possible evolution of novel strain(s) in the region is recommended.

Introduction

Tomato (*Solanum lycopersicum* L.), is amongst the most valuable vegetable crops grown worldwide. In Nigeria, tomato is cultivated in both wet and dry seasons of the year by the teaming resource-poor farmers as their sole means of livelihood (Abraham et al., 2019a). About 18% of the average daily vegetable consumption in Nigerian homes constitutes tomato fruits (Chidi, 2012). These fruits play a vital role in humans' diets as sources of vitamins (A, B and C), antioxidants (carotenoids such as β-carotene), sugars, minerals, dietary fibre and proteins (Olaiya, 2011; Alarcón-Flores et al., 2016). Based on tomato production, Nigeria is ranked 15th in the world, second in Africa, and first in Sub-Saharan Africa, producing 3.8 million tonnes of tomato in 2019. Between 2015 and 2019, the tomato cultivatable area in Nigeria was

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increased by 278,820 ha, but the yield was recorded to have decreased by 3 tonnes/ha (http://www.fao.org/faostat/en/#data/QC).

Numerous abiotic and biotic stresses influence plant growth, development, and yield (Huang et al., 2015). Out of over 136 species of viruses reported to infect tomato, *Tomato yellow leaf curl virus* (TYLCV; genus *Begomovirus*, family Geminivirdae) causing Tomato yellow leaf curl disease (TYLCD), which is the global most annihilating in tomato cultivation (Patil, 2020) where up to 100% tomato yield loss is incurred in susceptible cultivars (Levy and Lapidot, 2008; Patil, 2020). It constitutes a 20 x 30 nm geminate particle encapsidating a circular ssDNA genomic molecule of 2787 nt (Czosnek, 2020). *Bemisia tabaci* (family *Aleyrodidae*, order *Hemiptera*) is the principal vector that transmits TYLCV between tomato plants in a circulative manner (Prasad et al., 2020). Typical disease symptom expression on tomato plants due to TYLCV infection include: chlorosis, upward and inward leaf curling, a proliferation of lateral branches, puckering of terminal leaves, shedding of flower, premature fruit fall, reduced fruit size and stunted growth (Kashina et al. 2003; Kashina, 2017). The severity of disease symptoms and reduction in yield is determined by the age and developmental stage of the plant at which infection occurs (Nono-Womdim, 2003). TYLCD is geographically distributed across the Middle East, Southeast, and Central Asia, West and North Africa, Southeast Europe, Australia, Southeast USA, and the Caribbean Islands (Czosnek, 2020). Recently, TYLCV has been reported to occur in tomato Sudan savanna regions of Nigeria where lies the bulk of its production in the country (Abraham et al., 2019a). The effort to manage virus diseases is further complicated by the abundance of weed species serving as alternative hosts of plant viruses either in cultivation season or crop-free periods in the fields (Aguiar et al., 2018). TYLCV is documented to have a wide host range including both crops and weed species as reviewed by Prasad et al. (2020). Weeds, seeds and propagules have been identified as the common means of plant virus survival and transmission (Asala et al., 2014; Kumar et al., 2021). Viruses could live in dormant seeds, weeds or propagules, serving as inoculum that infects developed seedlings in the next cropping season (Alegbejo and Kashina, 2000; Odedara et al., 2008). The persistent feature of most weeds in nature due to their ability to thrive under a wide range of edaphic and climatic conditions, make them suitable alternative hosts or reservoirs for the survival of plant viruses and possible transmission to field crops. The first effective management step for virus diseases in screen house and fields, relied on the accurate detection of these viruses in their principal host crops and alternative weed hosts using serology and molecular techniques (Sastry and Zitter, 2014), as most farmers are not conversant with virus disease symptoms while most of the infected weed hosts expressing no symptoms. Identification of alternative weed host species of TYLCV within and around tomato fields will give a better understanding of the virus epidemiology and significant for its effective management (Abraham et al., 2019b). Bello et al. (2017) earlier reported three weeds species as alternative hosts of TYLCV from two States (Sokoto and Zamfara) in northern Nigeria. Hitherto, this information remains unexplored in other major tomato producing States in the country. In this present study, we report the detection of weed species infected with TYLCV in tomato fields in Sudan savanna (Gombe, Kano, and Jigawa States) Nigeria.

Materials and Methods

Survey and sampling sites

Surveys for weed hosts of TYLCV were conducted during 2017 and 2018 dry and wet cropping seasons in Gombe, Jigawa and Kano States of Nigeria. Three farms each from three major tomato producing Local Government

Areas (LGAs) were surveyed per State (GEMSA4, 2016). Three farms each across three major tomato producing LGAs of each State (Gombe: Akko, Kaltungo, and Yamaltu-Deba LGAs; Jigawa: Hadejia, Kirikasama, and Kazaure LGAs while in Kano: Garun Mallam, Bagwai and Kura LGAs) were surveyed.

Weed collection and identification

Ten symptomatic and asymptomatic weed samples per farm (n = 1080) were randomly collected within and around tomato farms. Weed samples were individually sealed in polyethylene bags, labelled and kept on an ice chest. Identification of the weed samples was done at the herbarium of the Department of Botany, Faculty of Life Sciences, Ahmadu Bello University, Zaria, and as described by Akobundu et al. (2016). Collected samples were transported to the Virology Laboratory of the Department of Crop Protection, Ahmadu Bello University Zaria for analyses. Samples were stored at 4 °C before diagnosis.

Serological assay

Collected weed samples were indexed for TYLCV using a triple-antibody sandwich enzyme-linked immunosorbent assay (TAS-ELISA) kit supplied by Leibniz-Institute DSMZ – Deutsche Sammlung von Mikroorganismen und Zellkulturen Gmbh, Braunschweig, Germany according to the manufacturer's instruction. The antigen-antibody reactions were detected and optical density of each well was measured after 1 h using an ELISA plate reader Uniequip (Martinseed, Germany) at a wavelength of 405 nm (Clark and Adams, 1977). Positive (tomato leaf sample infected with TYLCV obtained from DSMZ, Germany) and negative (healthy tomato leaves) controls were included in each plate. Sample values at least twice that of the negative control were rated positives (Kumar, 2009). Weed species that tested positive against TYLCV in both dry and wet seasons were considered as a host of the virus.

Data analysis

Data obtained on TYLCV incidence were subjected to analysis of variance. Means comparison was considered significant at 5% level of probability using either least significant difference (LSD) or by plotting standard error of means as described by Gomez and Gomez (1984).

Results

A total of 14 weed species within 12 families were detected as hosts of TYLCV with significant ($p \leq 0.05$) variation in their occurrence across the surveyed States. Gombe State had significantly ($p \leq 0.05$) the highest number (7) of TYLCV weed hosts (*Acanthospermum hispidum* DC., *Euphorbia hirta* L., *Cassia obtusifolia* L., *Ipomea asarifolia* (Desr.) Roem. & Schult., *Oldenlandia herbacea* (Linn.) Roxb., *Spermacoce verticillata* Linn. and *Amaranthus spinosus* L.) (Fig. 1, Table 1) but comparable to the number (7) of TYLCV weed hosts Kano (*Ageratum conyzoides* L., *Acanthospermum hispidum* DC., *Euphorbia hirta* L., *Commelina benghalensis* L., *Physalis angulata* L., *Portulaca oleracea* L. and *Leonotis nepetifolia* (L.) Ait. f.) recorded in Kano State (Fig. 1, Table 3); while Jigawa State had the lowest number (4) of TYLCV weed hosts (*Cassia obtusifolia* L., *Malvastrum coromandelianum* (Linn.) Garcke, *Corchorus trilocularis* L., and *Spermacoce verticillata* Linn.) as seen in Figure 1 and Table 3. *C. obtusifolia* significantly ($p \leq 0.05$) had the highest TYLCV frequency rating of 12.1%; while *L. nepetifolia*, *M. coromandelianum*, *C. trilocularis,* and *O. herbacea* recorded the lowest TYLCV frequency of 5.2 % (Fig. 2).

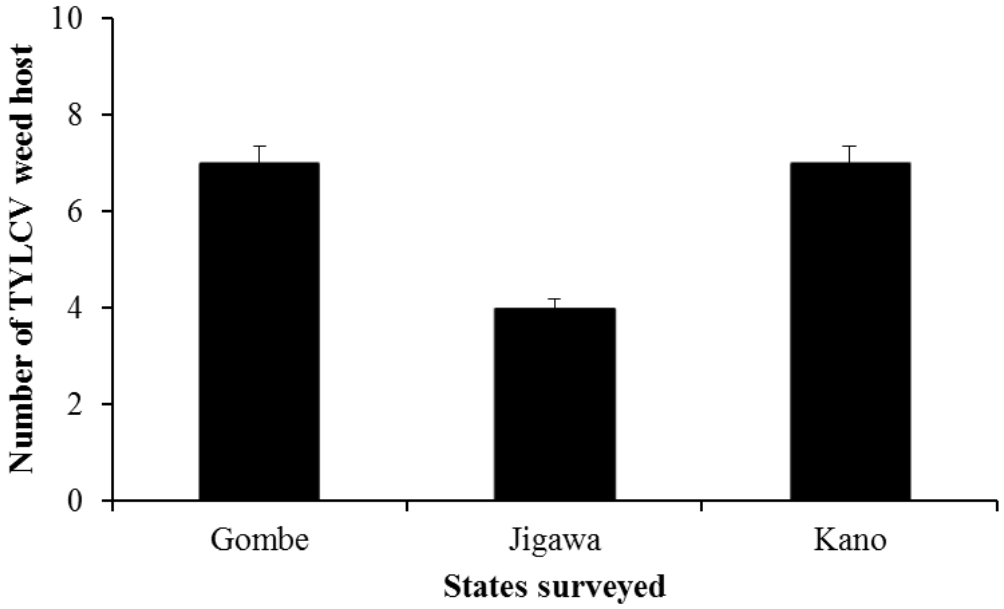

Fig. 1. Number of weed species detected as alternative weed hosts of *Tomato yellow leaf curl virus* (TYLCV) in the Gombe, Jigawa and Kano States of Nigeria. Bars indicate standard error of means at 5% probability level.

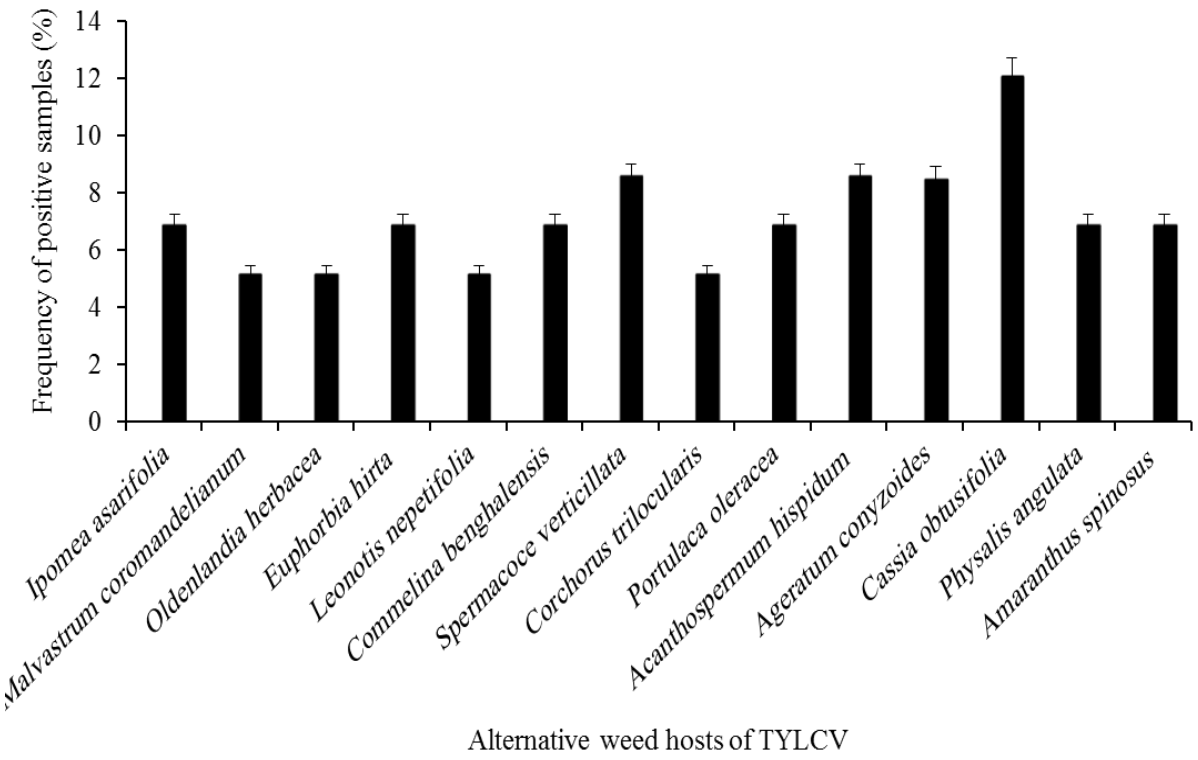

Fig. 2. Frequency (%) of positive samples detected in alternative weed hosts of *Tomato yellow leaf curl virus* (TYLCV). Bars indicate standard error of means at 5% probability level.

Table 1. Weed species tested against antisera of *Tomato yellow leaf curl virus* (TYLCV) in Gombe State of Nigeria during 2017 and 2018 dry and wet seasons

Families/Weed species	Common name	TYLCV Year/Season			
		2017		2018	
		DS	WS	DS	WS
Asteraceae					
Tridax procumbens	Coat buttons	-	-	-	-
Ageratum conyzoides L.	Goat weed	+	-	+	-
Apilia Africana (Pers) D.C.	Haemorrhage plant	NF	-	NF	-
Chromolaena odorata (L.) R. M.	Siam weed	-	NF	NF	-
Eclipta prostrata L.	False daisy	+	-	+	-
Venonia cinerea (Linn) Less	Little ironweed	-	NF	-	-
Venonia ambigua	Ironweed	-	-	NF	-
Acanthospermum hispidum DC.	Bristly starbur	-	+	+	-
Lactuca taraxacifolia (Willd.) Schum	Wild lettuce	-	-	NF	-
Lactuca serriola L.	Prickly lettuce	NF	-	-	+
Bidens pilosa Linn.	Cobblers peg	+	-	-	-
Euphorbiaceae					
Euphorbia hirta L.	Asthma plant	-	-	+	+
Phyllanthus amarus Schum.	Stone breaker	-	+	-	-
Euphorbia hyssopifolia Linn.	Breathless blush	-	-	NF	-
Euphorbia heterophylla Linn.	Spurge weed	-	+	-	+
Commelinaceae					
Commelina diffusa Burm. f.	Climbing dayflower	-	+	-	-
Commelina benghalensis L	Tropical spiderwort	-	-	+	-
Nyctaginaceae					
Boerhavia diffusa L.	Red spiderling	-	-	-	+
Sterculiaceae					
Waltheria indica Linn.	sleepy morning	NF	-	-	-
Solanaceae					
Physalis angulata L.	wildcape gooseberry	-	+	-	+
Solanum nigrum	Black nightshade	-	-	+	-
Physalis micranta Link.	Slender gooseberry	NF	-	+	-
Schwenckia Americana L.	Tabaco Cimarrón	NF	-	-	-
Portulacacea					
Portulaca oleracea L.	Common purslane	-	+	NF	-
Portulaca quadrifida Linn.	Ten o'clock plant	NF	-	-	-
Lythraceae					
Ammannia baccifera ssp. aegyptiaca W. Koehne	Blistering Ammania	-	NF	-	NF
Ceasalpiniaceae					
Cassia occidentalis Linn.	Coffee senna	+	-	+	-
Cassia obtusifolia L.	Sickle senna	-	+	+	+
Cassia mimosoides Linn.	Japanese tea	NF	-	-	-
Convolvulaceae					
Ipomea asarifolia (Desr.) Roem. & Schult.	Ginger-leaf morning-glory	+	+	+	+
Ipomea eriopcarpa R. Br.	Tiny morning glory	-	+	-	-
Ipomea vagans Bak.	-	-	-	-	-
Merremia aegyptica (Linn.)	Hairy woodrose	NF	-	NF	-
Malvaceae					
Sida corymbosa R. E. Fries	Broomweed	-	-	+	NF
Sida rhombifolia L.	Arrowleaf sida	-	-	-	+
Sida acuta Burm f.	Common wireweed	-	-	+	-

Table 1. Weed species tested against antisera of *Tomato yellow leaf curl virus* (TYLCV) in Gombe State of Nigeria during 2017 and 2018 dry and wet seasons (Continude)

Families/Weed species	Common name	TYLCV Year/Season			
		2017		2018	
		DS	WS	DS	WS
Tiliaceae					
Corchorus trilocularis Auct.	Cotton weed	-	+	-	-
Urena lobata Linn.	Hibiscusbur	NF	+	-	+
Cleomaceae					
Cleome viscosa L.	Spider plant	-	-	-	-
Cleome rutidosperma D.C.	Sringed spiderflower	-	-	-	NF
Rubiaceae					
Oldenlandia herbacea (Linn.) Roxb.	Slender oldenlandia	+	+	NF	+
Oldenlandia corymbosa Linn.	White diamond flower	NF	-	-	NF
Spermacoce verticillata Linn.	False buttonweed	+	-	+	+
Mitracarpus villosus (Sw.) DC.	Tropical girdlepod	-	+	-	+
Diodia scadens Sw.	Diodia	NF	-	NF	-
Lamiaceae					
Platostoma africanum P. Beauv.	-	-	NF	-	-
Leonotis nepetifolia (L.) Ait. f.	Lion's tail	-	-	+	-
Selonostenum monostachyus	Monkey's potato	-	-	-	-
Amaranthaceae					
Amaranthus spinosus L.	Spiny pigweed	+	+	+	+
Gomphrena celosioides Mart.	Water globehead	-	-	+	NF
Celosia laxa Schum. & Thonn.	Celosia	NF	NF	NF	-
Alternanthera pungens H. B. K.	Khaki weed	NF	-	NF	-
Fabaceae					
Alysicarpus ovalifolius (Schumach.) J. Leonard.	Over-leafed alysicarpus	-	-	-	-
Alysicarpus glumaceus (Vahl.) DC.	Long leaved alyce clover	-	-	-	-
Crotalaria retusa Linn.	Rattle box	NF	-	-	-
Desmodium scorpiurus (Sw.) Desv.	Beggerweed	-	NF	NF	-
Indigofera hirsuta Linn. *var. hirsute*	Hairy indigo	NF	-	-	-
Desmodium tortuosum (Sw.) DC.	Florida beggerweed	NF	-	-	-
Cucurbitaceae					
Luffa aegyptiaca Mill.	Loofah gourd	+	NF	-	NF
Momordica charantia Linn.	Balsam pear	-	-	NF	NF
Acanthaceae					
Hypoestes cancellata Nees.	-	-	-	NF	-
Nelsonia canescens L.	Blue pussyleaf	-	-	-	-
Urticaceae					
Fluerya aestuans (Linn.) ex Miq.	West Indian woodnettle	-	NF	NF	NF
Aizoaceae					
Trianthema portulacastrum Linn.	Horse purslane	NF	-	-	NF
Onagraceae					
Ludwigia decurrens Walt.	Willow primrose	NF	-	-	-

DS: Dry Season, WS: Wet Season, +: virus present, -: virus absent, NF: weed not found

Table 2. Weed species tested against antisera of *Tomato yellow leaf curl virus* (TYLCV) in Jigawa State of Nigeria during 2017 and 2018 dry and wet seasons

Families/Weed species	Common name	TYLCV YEAR/SEASON			
		2017		2018	
		DS	WS	DS	WS
Asteraceae					
Tridax procumbens	Coat buttons	NF	-	-	-
Ageratum conyzoides L.	Goat weed	-	-	NF	-
Apilia Africana (Pers) D.C.	Haemorrhage plant	-	NF	-	-
Chrysanthelium indicum	Indian chrysanthemum	NF	NF	-	+
Acanthospermum hispidum DC.	Bristly starbur	+	-	+	-
Venonia cinerea (Linn) Less	Little ironweed	NF	+	-	+
Lactuca serriola	Prickly lettuce	-	-	-	+
Euphorbiaceae					
Euphorbia hirta L.	Asthma plant	-	+	-	+
Phyllanthus amarus Schum.	Stone breaker	+	-	+	NF
Euphorbia hyssopifolia Linn.	Breathless blush	NF	-	+	NF
Euphorbia heterophylla Linn.	Spurge weed	-	NF	+	-
Commelinaceae					
Commelina erecta L.	Slender dayflower	+	-	-	NF
Commelina diffusa Burm. f.	Climbing dayflower	-	-	-	-
Commelina benghalensis L	Tropical spiderwort	+	-	+	-
Sterculiaceae					
Melachia corchorifolia Linn.	Chocolate-weed	NF	NF	-	-
Waltheria indica Linn.	Sleepy morning	-	NF	-	NF
Nyctaginaceae					
Boerhavia erecta L.	Erect spiderling	+	-	+	NF
Boerhavia diffusa L.	Red spiderling	-	-	-	+
Solanaceae					
Physalis angulata L.	Wildcape gooseberry	+	-	+	NF
Solanum nigrum L.	Black nightshade	+	-	+	-
Boraginaceace					
Heliotropium indicum Linn.	Indian heliotrope	NF	-	-	-
Portulacacea					
Portulaca oleracea L.	Common purslane	-	-	-	+
Portulaca quadrifida Linn.	Ten o'clock plant	-	-	-	-
Ceasalpiniaceae					
Cassia occidentalis Linn.	Coffee senna	-	NF	-	-
Cassia obtusifolia L.	Sickle senna	+	+	+	+
Cassia mimosoides Linn.	Japanese tea	+	-	-	-
Convolvulaceae					
Ipomea aquatica Forssk.	Water spinach	-	NF	-	-
Ipomea eriopcarpa R. Br.	Tiny morning glory	-	-	NF	-
Merremia aegyptia (Linn.) Urban	Hairy woodrose	-	-	-	NF
Melastomataceae					
Dissotis rotundifolia (Sm.) Triana	Pink lady	NF	-	NF	-
Malvaceae					
Sida corymbosa R. E. Fries	Broomweed	-	-	-	-
Hibiscus asper Hook f.	Bush Roselle	-	-	-	NF
Hibiscus sabdarifa	Red sorrel	-	-	-	-
Malvastrum coromandelianum (L.) Garcke	False mallow	-	+	+	+
Tiliaceae					
Corchorus trilocularis L.	Cotton weed	-	+	+	+
Cleomaceae					

Table 2. Weed species tested against antisera of *Tomato yellow leaf curl virus* (TYLCV) in Jigawa State of Nigeria during 2017 and 2018 dry and wet seasons (Continude)

Families/Weed species	Common name	TYLCV YEAR/SEASON			
		2017		208	
		DS	WS	DS	WS
Cleome viscosa L.	Spider plant	-	-	-	+
Cleome rutidosperma D.C.	Sringed spiderflower	NF	-	-	-
Cleome monophylla L.	Spindle pod	NF	-	NF	-
Rubiaceae					
Oldenlandia herbacea (Linn.) Roxb.	Stone breaker	-	-	NF	-
Spermacoce verticillata Linn.	False buttonweed	-	+	+	-
Mitracarpus villosus (Sw.) DC.	Tropical girdlepod	NF	-	-	-
Richardia brasiliensis Gomez	Mexican clover	NF	NF	-	-
Lamiaceae					
Platostoma africanum P. Beauv.	-	-	-	NF	+
Leonotis nepetifolia (L.) Ait. f.	Lion's tail	-	NF	-	-
Selonostenum monostachyus	Monkey's potato	NF	-	-	NF
Hyptes suaveolens Poit.	Bush tea	-	-	NF	-
Amaranthaceae					
Amaranthus spinosus L.	Spiny pigweed	+	-	+	-
Gomphrena celosioides Mart.	Water globehead	-	-	+	-
Amaranthus viridis	Slender amaranth	-	-	+	-
Chenopediaceae					
Chenopodium album L.	Common lambsquarter	NF	-	+	-
Fabaceae					
Alysicarpus ovalifolius (Schumach. & Thonn.)	Over-leafed alysicarpus	-	-	-	NF
Alysicarpus glumaceus (Vahl.) DC.	Long leaved alyce clover	-	-	NF	-
Desmodium scorpiurus (Sw.) Desv.	Beggerweed	-	-	NF	-
Tephrosia flexuosa	Wild indigo	+	NF	-	NF
Crotalaria retusa Linn.	Rattle box	NF	-	NF	-
Indigofera hirsuta Linn. var. hirsute	Hairy indigo	-	-	NF	NF
Cucurbitaceae					
Luffa aegyptiaca Mill.	Loofah gourd	+	NF	+	-
Momordica charantia Linn.	Balsam pear	-	-	NF	-
Polygonoceae					
Polygonum lanigenum R. Br.	Knotweed	+	-	NF	NF
Acanthaceae					
Hypoestes cancellata Nees.	-	NF	NF	-	-

DS: Dry Season, WS: Wet Season, +: virus present, -: virus absent, NF: weed not found

Table 3. Weed species tested against antisera of *Tomato yellow leaf curl virus* (TYLCV) in Kano State of Nigeria during 2017 and 2018 dry and wet seasons

Families/Weed species	Common name	TYLCV YEAR/SEASON			
		2017		2018	
		WS	DS	WS	DS
Asteraceae					
Acanthospermum hispidum DC.	Bristly starbur	+	+	-	+
Ageratum conyzoides L.	Goat weed	+	+	+	+
Apilia Africana (Pers) D.C.	Haemorrhage plant	-	-	-	NF
Bidens pilosa	Cobblers pegs	-	-	+	-
Lactuca serriola L.	Prickly lettuce	-	NF	+	-
Lactuca virosa Habl.	Wild lettuce	-	-	-	NF
Laggera aurita	-	+	-	-	-
Vernonia galamensis (Cass.) Less	Iron weed	NF	-	-	-
Euphorbiaceae					
Euphorbia hirta L.	Asthma plant	+	+	NF	-
Phyllanthus amarus Schum.	Stone breaker	-	+	-	+
Euphorbia heterophylla Linn.	Spurge weed	+	NF	-	-

Table 3. Weed species tested against antisera of *Tomato yellow leaf curl virus* (TYLCV) in Kano State of Nigeria during 2017 and 2018 dry and wet seasons (Continude)

Families/Weed species	Common name	TYLCV YEAR/SEASON			
		2017		2018	
		WS	DS	WS	DS
Jatropha curcas Linn.	Physic nut	-	-	+	-
Commelinaceae					
Commelina diffusa Burm. f.	Climbing dayflower	+	-	+	-
Commelina benghalensis L.	Tropical spiderwort	+	+	+	+
Commelina erecta L.	Slender dayflower	-	-	NF	+
Zygophyllaaceae					
Tribulus terestris L.	Puncture vine	NF	-	-	-
Solanaceae					
Physalis angulata L.	Wildcape gooseberry	+	+	+	+
Solanum nigrum	Black nightshade	+	-	+	-
Portulacacea					
Portulaca oleracea L.	Common purslane	+	+	+	+
Acanthaceae					
Nelsonia canescens (Lam.) Spreng.	Blue pussyleaf	NF	-	-	-
Ceasalpiniaceae					
Cassia obtusifolia L.	Sickle senna	+	-	+	-
Cassia mimosoides Linn.	Japanese tea	NF	-	-	-
Cassia occidentalis Linn.	Coffee senna	+	-	+	-
Convolvulaceae					
Ipomea triloba	Three-lobe morning glory	NF	-	-	-
Ipomea eriopcarpa R. Br.	Tiny morning glory	-	-	+	-
Malvaceae					
Sida corymbosa R. E. Fries	Broomweed	-	NF	-	-
Hibiscus asper Hook f.	Bush Roselle	NF	-	NF	-
Malvastrum coromandelianum (Linn.) Garcke	False mallow	-	+	NF	+
Urena lobata Linn.	Hibiscusbur	+	-	+	-
Tiliaceae					
Corchorus trilocularis L.	Cotton weed	+	-	+	-
Onagraceae					
Ludwigia decurrens Walt.	Willow primose	-	NF	+	NF
Rubiaceae					
Oldenlandia herbacea (Linn.) Roxb.	Stone breaker	NF	-	+	-
Oldenlandia corymbosa Linn.	White diamond flower	-	+	-	NF
Spermacoce verticillata Linn.	False buttonweed	-	+	-	+
Mitracarpus villosus (Sw.) DC.	Tropical girdlepod	-	+	-	-
Lamiaceae					
Mentha arvensis	Wild mint	+	NF	NF	NF
Leonotis nepetifolia (L.) Ait. f.	Lion's tail	+	-	+	+
Amaranthaceae					
Celosia argentiea L.	Silver Cockscomb	+	-	NF	-
Amaranthus spinosus L.	Spiny pigweed	-	+	+	-
Amaranthus viridis L.	Slender amaranth	+	-	+	-
Gomphrena celosioides Mart.	Water globehead	-	-	-	+
Chenopediaceae					
Chenopodium album L.	Common lambsquarter	NF	-	-	+
Fabaceae					
Alysicarpus glumaceus (Vahl.) DC.	Long leaved alyce clover	-	-	-	NF
Urticaceae					
Fluerya aestuans (Linn.) ex Miq.	West Indian Woodnettle	-	-	NF	-
Moraceae					
Ficus exasperata Vahl.	Sand paper tree	-	NF	-	NF

DS: Dry Season, WS: Wet Season, +: virus present, -: virus absent, NF: weed not found

Discussion

Many weed species either introduced or native have been found to serve as hosts of TYLCV and play a very significant role in the spread and epidemiology of TYLCV in tomato fields worldwide (Papayiannis et al., 2011). High incidences of plant viral diseases are influenced by weed hosts of their causative agents (Asala et al., 2014). The present study revealed that TYLCV naturally infecting weeds species in the three States (Gombe, Jigawa, and Kano) surveyed. TYLCV has earlier been reported to have a wide host range infecting both crop and weed species globally (Brunt et al., 1996; Papayiannis et al., 2011). Until now, three weed species (*Euphorbia hirta* L., *Physalis peruviana* L., and *Eclipta alba* L.) have been reported as hosts of TYLCV in north western part of Nigeria (Bello et al., 2017). Except for *Euphorbia hirta* L. as host of TYLCV, the present study documented for the first time the occurrence of 13 weed species within 11 families (*Convolvulaceae: Ipomea asarifolia* (Desr.) Roem. & Schult.; *Malvaceae: Malvastrum coromandelianum* (Linn.) Garcke; *Rubiaceae: Oldenlandia herbacea* (Linn.) Roxb., and *Spermacoce verticillata* Linn.; *Portulacacea: Portulaca oleracea* Linn.; *Asteraceae: Acanthospermum hispidum* DC., and *Ageratum conyzoides* L., *Ceasalpiniaceae: Cassia obtusifolia* L.; *Solanaceae: Physalis angulata* L.; *Amaranthaceae: Amaranthus spinosus* L.; *Lamiaceae: Leonotis nepetifolia* (L.) Ait. f.; *Commelinaceae: Commelina benghalensis* L.; and *Tiliaceae: Corchorus trilocularis* L.) as hosts of TYLCV in Northern Nigeria. Kashina et al. (2002) earlier reported 26 weed species as reservoir hosts of TYLCV in Tanzania. Similarly TYLCV was successfully detected in 49 weed species from 15 families in Cyprus (Papayiannis et al., 2011). The aggressive nature of the virus invasion and poor measures to contend its distribution makes it to be a worldwide pathogen (Prasad et al., 2020). On gaining entry to new environments, TYLCV tends to adapt to new native hosts and evolve novel strains via mutation and recombination (Péréfarres et al., 2012). Weeds detected as host of TYLCV in the present study were observed to be symptomless except for *A. hispidum*, *Spermacoce verticillata*, *Ipomea asarifolia* and *Physalis angulata*, which expressed leaf chlorosis, curling and reduced leaf size. This is in agreement with the report of Papayiannis et al. (2011) that most of the weeds infected with TYLCV show no symptoms. This uninterruptedly enhances the spread of the virus thereby making it a serious threat to the profitable production of tomato worldwide. The prevalence of these weed species as alternative hosts of TYLCV could be attributed to: their occurrence in high population and proximity with tomato crops; ability to thrive during both the cultivation and crop-free periods; naturally found to be infected with the virus and associated with its vector; farmers' unawareness about viral diseases; poor management of weeds species within and around the tomato fields. The high frequency of TYLCV observed in *C. obtusifolia* as one of the common weeds in tomato fields irrespective of the States surveyed suggests it to be the most stable and preferred weed host for TYLCV and its vector in the region.

Conclusion

The present study showed that TYLCV naturally infect 14 weed species from 12 families out of which 13 are reported for the first time as the hosts of TYLCV in Nigeria. The nature of the virus, characteristics, farmer's awareness about the virus as well as its vector, alternative weed hosts, and their management are factors that influence the incidence and spread of the virus in the studied area. The findings of the present study will give a further understanding of the epidemiology of the virus for its effective management. Exploring more weed hosts of TYLCV and molecular characterization of the virus in the host weeds for the possible evolution of novel strain(s) in the region is recommended.

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Conflict of Interest

The authors declare no conflict of interest for this study.

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