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BEMISIA TABACI (GENNADIUS) ABUNDANCE AND ITS RELATIONSHIP TO TOMATO YELLOW LEAF CURL VIRUS (TYLCV), WITH MOLECULAR CHARACTERIZATION, INCIDENCE AND EPIDEMIOLOGY IN TOMATO FIELDS, EGYPT

Adly D M[1], Abd El-Wahab A S[1]* and Ahmed A Kheder[2]

[1]Department of Economic Entomology and Pesticides,
Faculty of Agriculture, Cairo University, P O Box 12613, Giza, Egypt
*Email: dahabmokhtar@agr.cu.edu.eg; dahabmokhtar@gmail.com
[2]Virus and Phytoplasma Department, Plant Pathology Research Institute,
Agricultural Research Center, 12619, Giza, Egypt
Email: ahmed.zakaria@arc.sci.eg; ORCID ID 0000-0002-1647-5954
*Email: abeer5698987@yahoo.com, abeer5698987@agr.cu.edu.ed (corresponding author):
ORCID ID 0000-0001-7089-6066

ABSTRACT

This study monitored the whitefly *Bemisia tabaci* (Gennadius) populations and tomato yellow leaf curl virus (TYLCV) on tomato crops and nearby weeds over two seasons in Egypt. Whiteflies appeared in early March, peaked in late May, and reproduced actively, with nymphs predominant adults. Weeds, especially Jimsonweed, *Datura stramonium* L. and Cheeseweed mallow, *Malva parviflora* L. hosted higher *B. tabaci* densities than tomato plants, and sticky traps were more effective for detection than plant sampling. TYLCV infection in tomatoes was confirmed by Electron microscopy and Molecular analysis confirmed that the TYLCV isolate clustered with previously reported isolates in NCBI (GenBank Acc. No. PV890976.1), while the vector population was identified as *B. tabaci* biotype Q (GenBank Acc. No. PV902795.1). Transmission tests showed high TYLCV spread efficiency, and field incidence increased to 100% by mid-season, paralleling whitefly population growth. Viruliferous whiteflies were also found on multiple weeds, indicating their role as virus reservoirs. The study emphasizes integrated weed and vector management to reduce TYLCV spread.

Key words: Whitfly, *Bemisia tabaci*, TYLCV, tomato, weeds, epidemiology, vector relations, molecular characterization

Tomato (*Solanum lycopersicum* L.) is a major vegetable crop worldwide, contributing about 16% of global vegetable production and cultivated in over 161 countries, with Egypt ranking fifth in production (Xu et al., 2022). Tomato cultivation in Egypt occurs in both open fields and protected environments (Abbas et al., 2022) and is challenged by numerous pests, including *B. tabaci*, which damages crops through direct feeding, sooty mold induction, and virus transmission, causing 10–90% yield losses (Farina et al., 2022). *B. tabaci* is a cryptic species complex with over 40 morphologically indistinguishable species; the B (Middle East–Asia Minor 1) and Q (Mediterranean) biotypes are globally invasive and highly efficient virus vectors (Liu et al., 2013). Tomato Yellow Leaf Curl Virus (TYLCV), Begomovirus, Geminiviridae is one of the most important viruses transmitted by *B. tabaci*, in a persistent, circulative manner, with acquisition and transmission occurring within hours (Robin et al., 2023). Also, TYLCV was detected in some wild plants to serve as alternative hosts for the virus between growing seasons and as reservoirs of the virus in agroecosystems (Kil et al., 2021). Molecular tools, particularly PCR, are widely used to identify TYLCV and distinguish cryptic *B. tabaci* biotypes, facilitating epidemiological studies and management strategies (Hu et al., 2025;). This study examines the seasonal abundance of *B. tabaci*, its association with TYLCV, and the role of weeds in virus epidemiology in Egyptian tomato fields, providing insights for integrated vector–virus management. This study aims to investigate the seasonal abundance of *B. tabaci*, identify its biotypes using molecular tools, and assess the role of associated weed species as potential TYLCV reservoirs. The findings are expected to inform sustainable and effective management strategies for both the vector and the virus in Egypt's tomato production.

MATERIALS AND METHODS

The experiments were carried out at the Agricultural

Experimental Station, Faculty of Agriculture, Cairo University, Giza, Egypt (GPS: 30° 02′ N, 31° 13′ E) using tomato cultivar GS012. Standard agricultural practices were applied, excluding pest control measures. *B. tabaci* populations were direct monitored weekly on tomato plants and associated weeds using direct leaf counts (Ramos et al., 2019). Also count on different weeds associations with tomato plants (Amin, 1979) and indirect using yellow sticky traps (Gu et al., 2008). The viral particles that were isolated infected tomato plants have the typical symptoms of virus severe according to (Pan et al., 2012). The characterization of virus done by morphological and molecular, the morphological characterization crude sap of TYLCV was prepared and examined by Transmission Electron microscope JEOL (JEM-1400TEM, Japan) at the Electron Microscope Unit, Faculty of Agriculture, Cairo University, Research Park (CURP). using negative staining technique as described by (Noordam., 1973), The Molecular characteristics done through extracted DNA from TYLCV-infected plant tissues and *B. tabaci* adults according to (Dellaporta and Hicks, 1983). Viral DNA fragments were amplified using primers reported by (Accotto et al., 2000). Whitefly species confirmation was conducted via PCR targeting the mitochondrial 16S region according to (De Barro and Hart, 2000). Amplified products were gel-checked, purified, and sequenced in both directions. For phylogenetic inference, sequences were BLAST-searched against GenBank, aligned with ClustalW, and analyzed in MEGA 11 using Maximum Likelihood with 1000 bootstrap replications.

The study of virus transmission by three methods, firstly: mechanical inoculation, Viral inoculum was prepared according to (Bhat and Rao, 2020). Sceondly: Syringe injection, insulin syringes with a needle of 6mm × 31G were used, according to (Monroy -Borrego and Steinmetz, 2022). Third: insect transmission, Virus transmission by *B. tabaci* was carried out using two acquisition approaches. First, non-viruliferous adult *B. tabaci* were transferred onto TYLCV-infected tomato source was done as previously described by (Robin et al., 2023). Second, virus acquisition was also performed through artificial feeding described by (Upadhyay et al., 2011). Determination of natural incidence of viruliferous *B. tabaci* according to (Abd El-Wahab, 2021). The epidemiological incidence of TYLCV in each field was determined as the proportion of symptomatic plants relative to the total number of surveyed plants, following standard plant disease epidemiology procedures (Campbell and Madden, 1990). For higher accuracy, symptomatic and asymptomatic samples were further confirmed using molecular assays PCR.

RESULTS AND DISCUSSION

Occurrence of *B. tabaci* on tomato plants, different weed species and yellow sticky traps: Results presented in (Fig. 1A); *B tabaci* was consistently present during both growing seasons. Mean densities (46.0 and 50.56 individuals/plant in the first and second seasons, respectively) (Fig. 1 B, C). Seasonal monitoring revealed a similar population pattern across years, beginning in early March, gradually increasing through spring, and reaching maximum levels in late May before declining by mid-June. Nymphs consistently outnumbered adults. These results agree with earlier ones on populations, which increase steadily during spring and peak under warm, dry conditions (Patel et al., 2021; Li et al., 2022; Tomar et al., 2024). The observed population peaks in late May identify a critical period for management interventions in tomato fields. The higher second-season densities may reflect favorable climatic conditions or greater availability of alternative weed hosts. Occurrence of *B. tabaci* on weed hosts and their epidemiological role revealed that weeds associated with tomato fields supported substantial populations in both seasons. Seven weed species were infested in the first season and six in the second (Fig. 2A), indicating a dynamic weed community. *Datura stramonium* and *Malva parviflora* supported the highest densities in the first and second seasons,

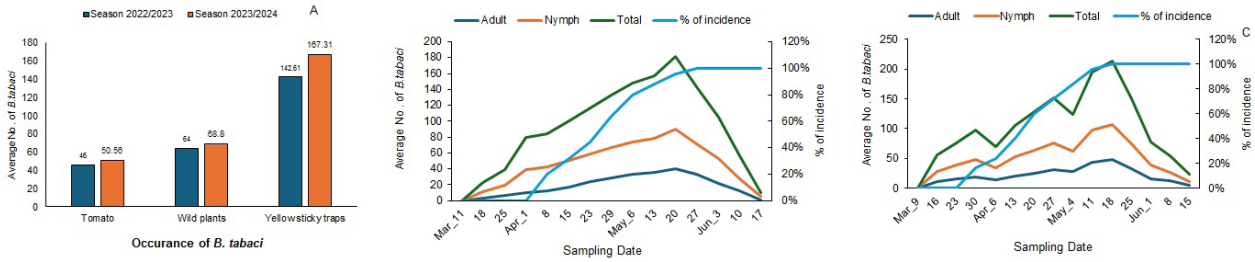

Fig. 1. A: Occurence of *B. tabaci* on tomato, weeds, and sticky traps; B: Seasonal abundance of *B. tabaci* and incidence of TYLCV (2022/2023); C: Seasonal abundance of *B. tabaci* and incidence of TYLCV (2023/2024).

respectively, whereas *Portulaca oleracea* consistently held the lowest numbers. Seasonal population trends on weeds resembled those observed on tomato, with gradual increases from March, peaks in late May, and sharp declines thereafter (Fig. 2 B, C). Weeds exhibited slightly higher overall *B. tabaci* densities than tomato plants. This suggests that many weeds serve as preferred hosts, contributing to the persistence and dispersal of *B. tabaci* within the tomato field. Similar conclusions have been reported by (Liu et al., 2022; Naranjo et al., 2010), who noted that whiteflies often exploit diverse weed hosts, especially when crop plants deteriorate late in the season. The presence of TYLCV in several weed species known to harbor *B. tabaci* (*D. stramonium C. arvensis*, *M. parviflora*, *S. nigrum*, e.g.,) underscores their role as virus reservoirs and "green bridges" between cropping cycles (Papayiannis et al., 2011).

Yellow sticky traps captured significantly higher numbers of *B. tabaci* than direct plant counts, with seasonal averages of (142.61 and 167.31 individuals/ trap) in the two seasons (Fig. 2D). Populations peaked in the eleventh week (227.4 and 264.2 individuals/ trap), corroborating plant-based observations.These findings demonstrate that sticky traps are effective for early detection and monitoring population trends, results supported by previous reports (Moerkens et al., 2019; Raghavendra et al., 2024). Their sensitivity makes them an essential tool for integrated pest management (IPM), especially during early crop establishment. Tomato plants exhibited identical TYLCV symptoms; leaf curling, inter-venial yellowing, stunting, and flower abscission, (Fig. 3 A-E) while fruits remained symptomless. Symptoms are consistent with those observed worldwide (Robin et al., 2023). The detection of TYLCV in multiple weed species further emphasizes their epidemiological significance as virus reservoirs. This supports previous findings that weeds contribute to TYLCV survival between seasons (Kil et al., 2021). Virus characteristics, electron microscopic examination of the partially crude sap of 22 nm and 20 x 30 nm to 24 x 30 nm, respectively. This result in an agreement with (Xie et al., 2013). Molecular characteristics, PCR amplification and sequencing confirmed the identity of the TYLCV isolate and *B. tabaci* biotype. The viral isolate (TYLCV-Eg) yielded a 540 bp fragment and shared 94.1–98.9% nucleotide identity with TYLCV isolates available in GenBank, showing highest similarity (98.9–98.6%) to the TY7 isolate from Egypt and the SE: Imp:4:09 isolate from Sweden (Table 1). Whitefly mitochondrial 16S rRNA sequences ~500 bp matched *B. tabaci* biotype Q,. Phylogenetic analyses supported these findings, clustering the EG-Q sequences with previously reported Q biotype sequences (Fig. 4 A-C) (Alhudaib et al., 2014).

Three methods were used to prove the transmission of the virus. The first method was mechanical inoculation; this method gave negative results. That means the TYLCV cannot transmission by sap of virus this results agreement with (AbdElKareem et al., 2023) when using tomato as a test plant, while, its disagreement with (Dhaliwal et al., 2020), when using (*D. stramonium*) as a test plant the % of mechanical

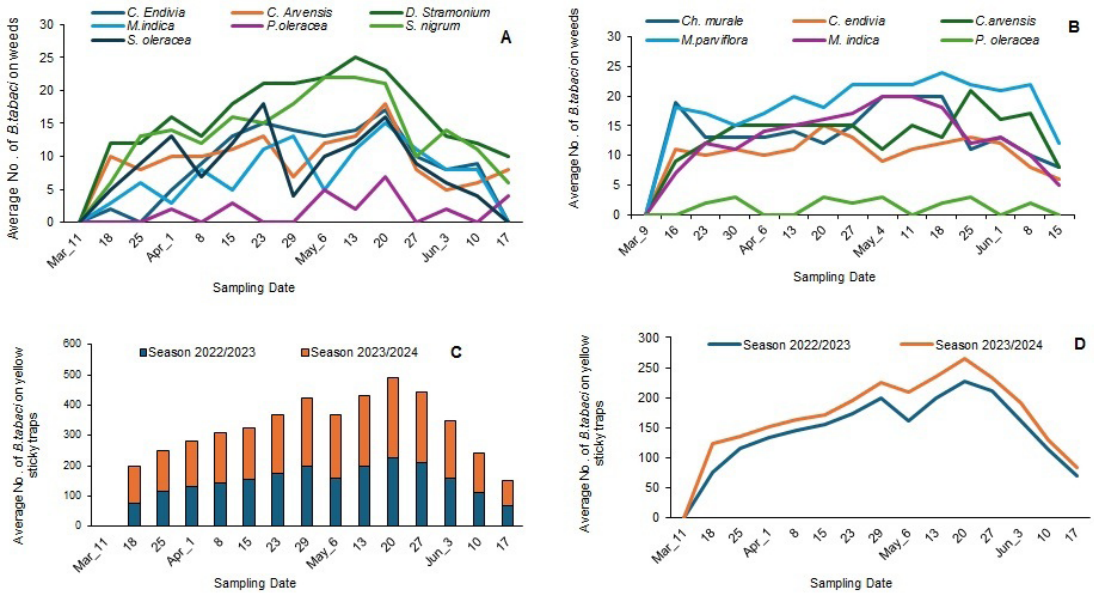

Fig. 2. Seasonal abundance of *B. tabaci* A: on weed hosts (2022/2023); B: on weed hosts (2023/2024); C: Occurrence on yellow sticky traps; D: Seasonal abundance on yellow sticky traps

Table 1. Comparison of the nucleotide sequences of the Tomato yellow leaf curl virus (TYLCV) (PV890976.1) with corresponding sequences

Acc. No.	Geographic origin	Isolate	Host	%Id
PV890976.1	Egypt	TYLCV-Eg	*Solanum lycopersicum*	--
KT921307.1	Egypt	TY7	*Solanum lycopersicum*	98.9%
HF548830.1	Sweden	SE: Imp: 4:09	*Solanum lycopersicum*	98.6%
EF107520.1	Egypt	TYLCV-Nob	*Solanum lycopersicum*	98.0%
MT084806.1	China	App	*Malus domestica*	97.9%
X76319.1	Israel	Mild	-	97.9%
KF990598.1	Tunisia	3/012	*Solanum lycopersicum*	97.9%
AF058020.1	Israel	Israel field	-	97.9%
MK521832.1	South Korea	JP-B4	*Solanum lycopersicum*	97.9%
MF429946.1	Iraq	IQ Na-4 Tomato 15	Tomato	97.7%
KU958505.1	Tunisia	PA1--09	Watermelon	97.7%
MK521836.1	South Korea	JP-D1	*Solanum lycopersicum*	97.7%
JX075187.1	South Korea	South Korea	Tomato	97.7%
MK521831.1	South Korea	JP-B3	*Solanum lycopersicum*	97.7%
DQ058101.1	Spain	E14-1	-	97.5%
MF429948.1	Iraq	IQ Na-32 Tomato 14	Tomato	97.5%
EF625895.1	Venezuela	Zulia66L-Mild	Tomato	97.2%
KF990599.1	Tunisia	51/012	*Solanum elaeagnifolium*	97.1%
KC762975.1	China	LN5	*Bemisia tabaci*	96.9%
HF548838.1	Estonia	EE: Imp: 8:08	*Solanum lycopersicum*	96.7%
DQ058103.1	Spain	J - Almeria	-	96.7%
HF548834.1	Estonia	EE: Imp: 4:08	*Solanum lycopersicum*	96.7%
EF122598.1	China	Shanghai	Tomato	94.1%

transmission reached 17%. The second method is syringe injections that give positive results with 100% when used 20 test plant all of them appear symptoms after 2-5 weeks. This result agrees with (El-Dougdoug et al., 2010; El-Monem et al., 2011); they are using syringe injections to transmit TYLCV, and (Monroy-Borrego and Steinmetz, 2022) they are using syringe injections to transmit TMV, but this result disagrees with (Abd ElRahman et al., 2024). The third method insct transmiions artificial feeding of whiteflies biotype Q, gives positive results with 75% when used 20 test plant only 15 plant appear symptoms this results similar with (Sánchez-Campos et al., 2016) and (Thesnim et al., 2023), they are using artificial diet to confirmation the

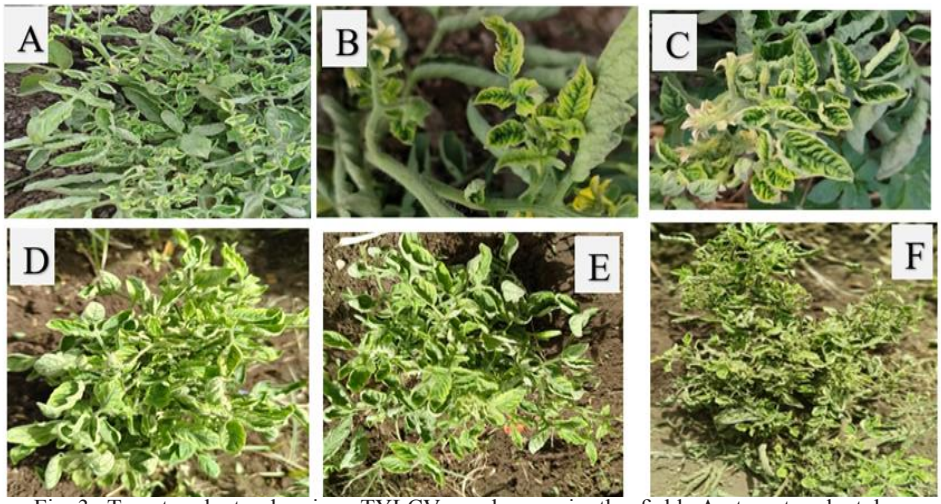

Fig. 3. Tomato plants showing, TYLCV syndromes in the field A: tomato plant has severe leaf curling, leaf crinkle with marginal yellowing; B and C: leaf crinkle with marginal yellowing; D and E: stunted, severe leaf curling; F: severe leaf curling, leaf crinkle with marginal yellowing, twisted, and stunted stems

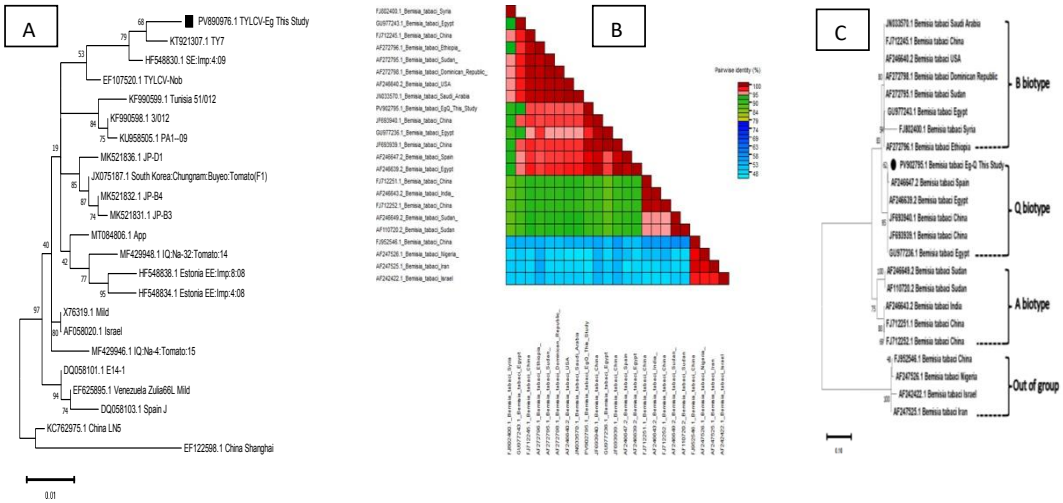

Fig. 4. A: phylogenetic tree of TYLCV isolate (TYLCV-Eg) used in this study (■). B&C:The percentage of nucleotide identities of the mitochondrial 16S rRNA gene of whiteflies (Eg-Q) collected from the Giza governorate was calculated using the Sequence Demarcation tool (SDT v1.3).

ability of *B. tabaci* to transmission the Chilli leaf curl virus (ChiLCV). Transmission by *B.tabaci* biotype Q feeding on plant of virus source gives positive results with 95% when used 20 test plant only 19 plant appear symptoms *B. tabaci* transmitted TYLCV by persistent circulative manner, this results agreement with (Haq et al., 2018; Robin et al., 2023). The 24-hr acquisition and inoculation access periods observed confirm efficient vector-virus interaction.

Field surveys revealed that TYLCV incidence began in late March to early April (16–20%), increasing

Table 2. Natural Incidence of viruliferous *B. tabaci* biotype Q carrying (TYLCV) from tomato and pepper and associated wild plants (Giza, 2022\2023 and 2023/2024)

Plant Host/ Scientific Name	Common Name	First season		Second season	
		*I/** T	%	* I/** T	%
Amaranthaceae	Lamb's quarters	-	-	1/20	5 %
1-*Chenopodium murale*					
Asteraceae	Sow thistle	1/20	5%	-	-
1- *Sonchus oleraceus*	*Batavia Endive,*	0/10	0	0/20	0
2- *Cichorium endivia*	*Escarole and Frisée*				
Convolvulaceae					
3-*Convolvulus arvensis*	Field Bindweed	1/20	5%	2/20	10%
Fabaceae					
4-*Melilotus indicus*	sweet clover	3/19	15.7%	4/20	20%
Malvaceae					
5-*Malva parviflora*	Cheese weed	-	-	1/20	5%
Portulacaceae					
5- *Portulaca oleracea*	Common purslane	0/20	0	0/20	0
Solanaceae	Tomato	18/20	90%	19/20	95%
6- *Solanum ycopersicon*	Pepper	12/20	60%	13/20	65%
7- Capsicum annuum	European Black	8/20	40%	-	-
8- *Solanum nigrum*	nightshade	7/20	35%	-	-
9- *Datura stramonium*	Jimson Weed				
Total (%)		50/169	29.59%	40/160	25%

*I/T = No. of Infected plants. **No. of tested ones at least 10 individuals from each species were tested.
***%= Percentage of infection.
- Weed did not available

steadily to reach 100% by the eleventh or twelfth week in both seasons (Fig. 1 B, C). The temporal pattern of disease incidence strongly mirrored *B. tabaci* population dynamics, indicating a direct relationship between vector abundance and virus spread. Such positive correlations are well documented for TYLCV epidemiology (Haq et al., 2018; Anco et al., 2020; Lobin et al., 2022). High proportions of viruliferous *B. tabaci* were detected on tomato (90–95%), pepper (60–65%), and several associated weeds (Table 2). Infection levels varied among weed species, with *S. nigrum* (40%) and *D. stramonium* (35%) showing the highest rates, while *C. endivia* and *P. oleracea* tested negative. These results illustrate that both crop and non-crop hosts play key roles in maintaining TYLCV throughout the season. The detection of TYLCV-positive *B. tabaci* on several weed species highlights their importance as virus reservoirs and necessitates their inclusion in management strategies, consistent with previous reports (Sastry et al., 2019).

AUTHOR CONTRIBUTION STATEMENT

Dahab Mokhtar Adly: Conceived and designed the research, conducted field experiments, and drafted the manuscript. Abeer Salah El-Deen Abd El-Wahab and Ahmed Abd El Aziz Kheder supervised the work and implementation of the research, to the analysis of the results and to the writing of the manuscript. All authors read and approved the final version of the manuscript.

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CONFLICT OF INTEREST

No conflict of interest.

REFERENCES

Abbas M, Li Y, Elbaiomy R G, Yan K, Ragauskas A J, Yadav V, El-Sappah AH. 2022. Genome-wide analysis and expression profiling of SlHsp70 gene family in *Solanum lycopersicum* revealed higher expression of SlHsp70-11 in roots under Cd^{2+} stress. Frontiers in Bioscience-Landmark 27(6): 186.

Abd ElKareem H A, Nasr-Eldin M A, Ahmed S A, Abdelwahed M A, Soliman E R. 2023. Molecular validation for impossible transmission of TYLCV through mechanical route. Benha Journal of Applied Sciences 8(5): 185-190.

Abd ElRahman H, Nasr-Eldin M A, Abo-Elmaaty S A, Abdelwahed M A, ElHefnawi M, Elfiky A M, Soliman E R. 2024. Partial genome detection, characterization of TYLCV (MZ546492) infecting tomato plants and siRNA sequences detection for alternative control strategy. Egyptian Journal of Botany 64(1): 211-223.

Abd El-Wahab A S. 2021. Molecular characterization and incidence of new tospovirus: Soybean Vein Necrosis Virus (SVNV) in Egypt. Brazilian Journal of Biology 84: e246460.

Accotto G P, Navas-Castillo J, Noris E, Moriones E, Louro D. 2000. Typing of tomato yellow leaf curl viruses in Europe. European Journal of Plant Pathology 106: 179-186.

Amin A H. 1979. Studies on the aphid fauna of wild plants in Egypt with special reference to aphid-borne viruses. MSc. Thesis, Faculty of Agriculture, Cairo University, Egypt, 121 pp.

Anco D J, Rouse L, Lucas L, Parks F, Mellinger H C, Adkins S, Turechek W W. 2020. Spatial and temporal physiognomies of whitefly and tomato yellow leaf curl virus epidemics in southwestern Florida tomato fields. Phytopathology 110(1): 130-145.

Alhudaib K A, Rezk A A S, Abdel-Banat B M A, Soliman A M. 2014. Molecular identification of the biotype of whitefly (*Bemisia tabaci*) inhabiting the eastern region of Saudi Arabia. Journal of Biological Sciences 14(8): 494-500.

Bhat A I, Rao G P. 2020. Mechanical sap transmission. In: Characterization of Plant Viruses: Methods and Protocols. Springer US, pp. 39-43.

Campbell C L, Madden L V. 1990. Introduction to plant disease epidemiology. Wiley.

De Barro P D, Hart P J. 2000. Mating interactions between two biotypes of the whitefly, *Bemisia tabaci* (Hemiptera: Aleyrodidae) in Australia. Bulletin of Entomological Research 90(2): 103-112.

Dhaliwal M S, Jindal S K, Sharma A, Prasanna H C. 2020. Tomato yellow leaf curl virus disease of tomato and its management through resistance breeding: a review. The Journal of Horticultural Science and Biotechnology 95(4): 425-444.

Dellaporta S L, Wood J, Hicks J B. 1983. A plant DNA minipreparation: version II. Plant Molecular Biology Reporter 1: 19-21.

El-Dougdoug K A, Hammad I A, Abd H S. 2010. Detection and identification of Tomato Yellow Leaf Curl virus-EG using molecular technique. Egypt Journal of Microbiology 45: 95-111.

El-Monem A, Asmaa F, El-Dougdoug K A, Hamad I A, Ahmed E A, El-Kader A, Hayam S. 2011. Identification and molecular characterization of Tomato Yellow Leaf Curl Virus-EG. Emirates Journal of Food and Agriculture 23(4).

Farina A, Barbera A C, Leonardi G, Massimino Cocuzza G E, Suma P, Rapisarda C. 2022. *Bemisia tabaci* (Hemiptera: Aleyrodidae): what relationships with and morpho-physiological effects on the plants it develops on? Insects 13(4): 351.

Gu X S, Bu W J, Xu W H, Bai Y C, Liu B M, Liu T X. 2008. Population suppression of *Bemisia tabaci* (Hemiptera: Aleyrodidae) using yellow sticky traps and *Eretmocerus nr. rajasthanicus* (Hymenoptera: Aphelinidae) on tomato plants in greenhouses. Insect Science 15(3): 263-270.

Haq G, Arif M, Ali A, Inaaullah M. 2018. Tomato yellow leaf curl virus in tomato crop of Khyber Pakhtunkhwa province: virus and vector prevalence and transmission properties. Sarhad Journal of Agriculture 34(3): 500-508.

Hu H, Zhang J, Wu X, Li L, Qian Y. 2025. Development and application of a multiplex PCR assay for simultaneous detection of Tomato Yellow Leaf Curl Virus and Tomato Leaf Curl New Delhi Virus. Viruses 17(3): 322.

Kil E J, Byun H S, Hwang H, Lee K Y, Choi H S, Kim C S, Lee S. 2021. Tomato yellow leaf curl virus infection in a monocotyledonous weed (*Eleusine indica*). The Plant Pathology Journal 37(6): 641.

Li M J, Yang S W, Chen G H, Dou W J, Shang H P, Zhang X M. 2022. Density and seasonal dynamics of *Bemisia tabaci* and its predators in different agricultural landscapes in South China. Frontiers in Plant Science 13: 928634.

Liu B, Preisser E L, Chu D, Pan H, Xie W, Wang S, Zhang Y, et al.

2013. Multiple forms of vector manipulation by a plant-infecting virus: *Bemisia tabaci* and tomato yellow leaf curl virus. Journal of Virology 87(9): 4929-4937.

Liu S, Yang Z, Volodymyr V. 2022. Importance of *Bemisia tabaci* forecasting technology: a review. Advances in Entomology 10(2): 149-158.

Lobin K K, Jaunky V C, Taleb-Hossenkhan N. 2022. A meta-analysis of climatic conditions and whitefly *Bemisia tabaci* population: implications for tomato yellow leaf curl disease. The Journal of Basic and Applied Zoology 83(1): 57.

Monroy-Borrego A G, Steinmetz N F . 2022. Three methods for inoculation of viral vectors into plants. Frontiers in Plant Science 13: 963756.

Moerkens R, Brenard N, Bosmans L, Reybroeck E, Janssen D, Hemming J, Sluydts V. 2019. Protocol for semi-automatic identification of whiteflies *Bemisia tabaci* and *Trialeurodes vaporariorum* on yellow sticky traps. Journal of Applied Entomology 143(6): 652–658.

Naranjo S E, Castle S J, De Barro P J, Liu S S. 2010. Population dynamics, demography, dispersal and spread of *Bemisia tabaci*. *Bemisia*: Bionomics and management of a global pest. Springer Netherlands, Dordrecht. pp. 185-226.

Noordam D. 1973. Identification of plant viruses. Methods and experiments.

Pan H, Chu D, Yan W, Su Q, Liu B, Wang S, Zhang Y. 2012. Rapid spread of tomato yellow leaf curl virus in China is aided differentially by two invasive whiteflies. PLoS One 7(4): e34817.

Patel C, Srivastava R M, Deeksha M G, Kunwar R, Tiwari J, Pal K. 2021. Influence of abiotic factors on seasonal incidence of *Bemisia tabaci* (Gennadius) on tomato. The Pharma Innovation Journal 10(10S): 1052-1055.

Raghavendra K V, Rekha B, Ramesh K B. Management of tomato yellow leaf curl virus: perspectives. Lapidot M, Polston J E (eds). Tomato yellow leaf curl viru*s* Disease: management, molecular biology, breeding for resistance, Springer Netherlands, Dordrecht. pp. 251-262.

Ramos R S, Kumar L, Shabani F, da Silva R S, de Araújo T A, Picanço M C. 2019. Climate model for seasonal variation in *Bemisia tabaci* using CLIMEX in tomato crops. International Journal of Biometeorology 63: 281-291.

Robin R, Kumar S, Kapoor S, Handa A. 2023. Evidence for upholding the association of whitefly species *Bemisia tabaci* and *Trialeurodes vaporariorum* with tomato yellow leaf curl virus. Plant Pathology Journal 22: 25-38.

Sánchez-Campos S, Rodríguez-Negrete E A, Cruzado L, Grande-Pérez A, Bejarano E R, Navas-Castillo J, Moriones E. 2016. Tomato yellow leaf curl virus: no evidence for replication in the insect vector *Bemisia tabaci*. Scientific Reports 6: 30942.

Sastry K S, Mandal B, Hammond J, Scott S W, Briddon R W. 2019. Encyclopedia of Plant Viruses and Viroids. Springer: New Delhi, India. 520 pp.

Thesnim P, Jangra S, Kumar M, Ghosh A. 2023. Effect of silencing *Bemisia tabaci* TLR3 and TOB1 on fitness and begomovirus transmission. Frontiers in Plant Science 14: 1136262.

Tomar N, Singh P, Sasode R S, Bhadauria N, Singh U, Seervi S, Suman S. 2024. Seasonal incidence of whitefly, *Bemisia tabaci* (Gennadius) on tomato in Gird region of Madhya Pradesh. Uttar Pradesh Journal of Zoology 45(17): 353-361.

Upadhyay S K, Chandrashekar K, Thakur N, Verma P C, Borgio J F, Singh P K, Tuli R. 2011. RNA interference for the control of whiteflies (*Bemisia tabaci*) by oral route. Journal of Biosciences 36(1): 153-161.

Xu Z, Pehlivan N, Ghorbani A, Wu C. 2022. Effects of *Azorhizobium caulinodans* and *Piriformospora indica* co-inoculation on growth and fruit quality of tomato (*Solanum lycopersicum* L.) under Salt Stress. Horticulturae 8(4): 302.

Xie Y, Jiao X, Zhou X, Liu H, Ni Y, Wu J. 2013. Highly sensitive serological methods for detecting tomato yellow leaf curl virus in tomato plants and whiteflies. Virology Journal 10(1): 142.

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