Chapter 4

Review on Tomato (*Solanum lycopersicum*, L.) Improvement Programmes in Ghana

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Additional information is available at the end of the chapter

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Abstract

Tomato is an important component of every Ghanaian meal, and its cultivation contributes significantly to livelihood improvement. The demand for tomato in Ghana outstrips supply, and therefore local production is augmented by imports from neighbouring countries. Despite the importance of tomato in Ghana, past tomato-breeding programmes have been unsystematic and had not led to the development of new varieties that meet the needs of consumers as well as environmental stresses. This review outlined tomato production trends, constraints and past tomato improvement programmes in Ghana, which mainly focused on germplasm collection, morphological and agronomic characterization, molecular evaluation, diversity study, as well as screening germplasm against biotic and abiotic stresses. The established variability and the outcomes of the evaluations against the various biotic and abiotic stresses have not been utilized in the development of new varieties. This work will serve as a reference for developing future tomato-breeding programmes.

Keywords: tomato, unsystematic, breeding programmes, agronomic, morphological, molecular

1. Introduction

Tomato (*Solanum lycopersicum,* L.) belongs to the *Solanaceae* family also called Nightshades, which include more than 3000 species [1]. Other examples of crops within the Nightshade family include pepper, potato, eggplants and tobacco. Tomato originated from the Andean region,

which is modern day Chile, Bolivia, Ecuador, Colombia and Peru; however, the original site of domestication is unclear [2]. Two hypotheses have been expressed for the original site of tomato domestication: one stipulates Peru and the other Mexico. It is, however, presumed that Mexico is probably the site of domestication and Peru is the centre of diversity [3]. Originally, tomatoes were pea-sized berries but domestication and plant breeding have resulted in increased fruit sizes [4].

Tomato continues to be the most important vegetable in the world due to increasing commercial and dietary value, widespread production as well as model plant for research [5]. Tomato is utilized as a fresh crop or processed into various forms such as paste, puree and juices. Tomato is a rich source of vitamins (A and C), minerals (iron, phosphorus), lycopene, Beta-carotene, high amount of water and low calories [6]. The five leading producers of tomato in the world are China, India, United States of America, Turkey and Egypt [7]. The world's tomato production in 2014 was 171 million tonnes with an average yield of 37 tonnes per hectare [8].

According to Norman [9], tomato (*S. lycopersicum*) was introduced into the geographical area considered modern day Ghana in the sixteenth century. Although the cultivation of tomato remains a subsistent farming activity, its cultivation and trade contributes significantly to livelihoods improvement [10]. Schippers [11] asserts that tomato is the most important vegetable in Ghana, compared to all the other vegetables. This view can be justified with the continuing increase in the demand for fresh and processed tomatoes in Ghana. With an average yield of about 8.1 tonnes per hectare in 2013, an estimated 340,218 tonnes of fresh tomatoes were produced locally and 5,945 tonnes was imported. In addition, 109,513 tonnes of processed tomatoes were imported within the year 2013 [12]. In the ensuing year, reported tomatoes statistics showed that there were increases in the local production volumes (366,772 tonnes), marching the increase in output per hectare of 8.6 t/ha [13]. The high volumes of tomato produced locally as well as imported are an indication of the importance of tomato in every Ghanaian meal.

Despite the importance of tomato in Ghana, tomato-breeding programmes over the years have not been systematic and therefore had not led to the development of new varieties that meet the needs of consumers as well as biotic and abiotic stresses [14]. The major goals of tomato breeding worldwide are increasing yield, tolerance to biotic and abiotic stresses and improvement in sensory and nutritional value of the crop [15]. Consequently, past Ghanaian plant breeders have focused on germplasm collection, evaluation of imported and local accession for morphological and agronomic traits as well as screening accessions for their reactions to biotic and abiotic stresses. Nonetheless, there have been little published breeding programmes in the past that focussed on improving fruit-quality traits or introgression genes that will make cultivars resilient to both biotic and abiotic stresses. In 2014, the Ghana National Tomato Federation stated that the union has been pushing government to support research in the development of high yielding and quality tomato variety suitable for local and export market [16]. This chapter therefore highlights tomato production trends in Ghana, tomato production constraints, past tomato-breeding programmes in the country and future tomato-breeding objectives, which will serve as a locus for developing future tomato-breeding programmes.

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2. Tomato production trends and constraints in Ghana

Tomato is mostly produced in seven out of the 10 regions in Ghana. These production regions include Upper East region, Northern region, Brong Ahafo region, Ashanti region, Eastern region, Greater Accra region and Volta region. The demand for both fresh tomato and tomato products is year round although tomato production in Ghana is seasonal due to the differences in the rainfall patterns as well as water availability. In the exception of the Upper East Region where tomato is produced during the dry season under furrow irrigation system and some parts of the Greater Accra region, tomato production is generally rain fed. During the rainy season, harvest is abundant, leading to glut and wastage even though there is scarcity during the dry season. The abundance of tomato during the rainy season results in low prices and low return on investment. Tomato produced during the rainy season is supplied to the market from May to October but the varieties produced during this period are poor in colour, watery, acidic and have a shorter shelf life, making them unsuitable for processing. Due to the unavailability of processing tomato varieties, all the three state-owned tomato-processing factories had to shut down. Tomato varieties that are currently grown by Ghanaian farmers are mostly imported varieties and farmers selected varieties. A very important open-pollinated variety (OPV) grown in Ghana particularly in the Brong Ahafo region is the Power Rano (a cross between Power and Laurano varieties) which was identified by the National Research Institute (NRI) researchers in the 1990s based on its good production and local processing qualities [17].

Dry season production in Ghana on the other hand is challenging, and demand is in excess of supply. This period partially coincides with the Christmas season when demand for tomato is at its peak. In order to meet the dry season demand, there is heavy importation of fresh tomato from neighbouring countries, particularly Burkina Faso to augment local supply. Some parts of the Greater Accra region such as Ashiaman, Tema and Weija grow tomato under irrigation system and mostly supply tomato unto the market from September to December, and the Upper East region then continues tomato supply from January to April**. I**mported tomato from Burkina Faso supplements local production 5–6 months of the year [18] with a peak supply from February to April [19]. It has been established that, with the availability of water and favourable night temperatures, the highest quality and fruit yield of tomato is obtained in the dry season [20]. In Ghana, the capacity for dry season tomato production lies in the savannah zones, particularly the Upper East, Volta and the Greater Accra regions since water for dry season irrigation is not a limiting factor in these regions. Tomato production halted in the Upper East region in 2002 due to Tomato Yellow Leaf Curl Disease (TYLCD) and a complex of fungal pathogens [21]. In addition, over 600 tomato farmers in the Agotime-Ziope District of the Volta region were reported to have lost virtually all their investment following the TYLCD infection (in 2014) of over 1000 hectares of tomato farms in the area [22]. A high night temperature, a high prevalence of TYLCD and inadequate irrigation facilities to channel the available water are characteristics of dry season production of tomato in the Greater Accra region. Ghana's inability to produce tomato during the dry season therefore has been attributed to a lack of irrigation facility, a high incidence of Tomato Yellow Leaf Curl Disease [23, 24] as well as high night temperatures [25].

3. Past tomato-breeding programmes in Ghana

Tomato-breeding programmes in Ghana can be traced to the 1950–1978 when cultivars like OK, MH and Wosowoso were developed. A major tomato-breeding programme led by the National Research Institute (NRI) in UK also carried out a study from 1994 to 2000. Post 2000, tomato improvement programmes focussed mainly on screening tomato germplasm for both biotic (particularly the TVLCD) and abiotic stresses as well as mutation breeding; however, none has led to the release of varieties. Robinson and Kolavalli in 2010 stated that since the NRI tomato-breeding work ended in 2000, there have been no breeding programmes and no systematic seed multiplication in the country [26]. Again, a 2013 publication indicated that the varieties developed during the 1950 to 1978 together with farmers' selection in tomato-growing areas have led to the development of large tomato ecotypes in Ghana [27].

3.1. Germplasm collection and genetic diversity studies

Germplasm is required for the commencement of any breeding programme. Consequently, the Council for Scientific and Industrial Research-Plant Genetic Resources Research Institute (CSIR-PGRRI) and the National Agriculture Research Programme periodically collected a number of tomato accessions from all the 10 regions in Ghana. The 2012 tomato germplasm collection by the Council for Scientific and Industrial Research-Crops Research Institute of Ghana (CSIR-CRI) included accessions from two districts in Burkina Faso (Kougoussi and Yako), Asian Vegetable Research Development Centre (AVRDC), Rural Development Administration (RDA), National Institute of Horticulture and Herbal Science (NIHHS) and Republic of Korea. This was funded by the Korea Africa Food and Agricultural Cooperation Initiative (KAFACI) project [28]. Recently, 13 accessions were also collected from Afari, Akumdan and Akuawu in the Ashanti region. The recent germplasm collected included accessions such as 'Atoa', 'Daagyine', 'Local 1', 'Power', Pectofake 1, Petomech, 'Akoma', Pectofake 2, Powerano, 'Bolga', 'Dwidwi' (cherry), 'Local 2' and Rano [29]. Most of the locally collected germplasm and introduced accessions have been evaluated for various agronomic and morphological traits as well as the establishment of genetic variation that exists within this germplasm. The Savanna Agricultural Research Institute evaluated three tomato varieties (ICRISIND, Petomech and Tropimech) for various agronomic traits. Variations were observed in plant height, days to flowering, number of fruits, fruit size and fruit weight [30]. Again in 2013, SARI evaluated the following accessions: S 22, Naywli, Bebi yereye, LBR 7, Keneya, LBR 17, Abhijay and Petomech for variability in various agronomic traits [31].

S. pimpinellifolium possesses some desirable traits that can be utilized to improve cultivated varieties; however, the size of the fruit is a hindrance to domestication. In order to improve on the size and other desirable traits, a group of researchers at the Biotechnology and Nuclear Agriculture Research Institute (BNARI) of the Ghana Atomic Energy Commission (GAEC) irradiated the seeds of *S. pimpinellifolium.* The variability of the elemental composition of five mutation-induced variant lines (M3 population; BV-27, BV-40, BV-21, BV-23, BV-10/27) of *S. pimpinellifolium* and the parental line was studied using Instrumental Neutron Activation Analysis (INAA). The results showed a significant variation in the concentration of elements (Na, K, Ca, Mg, Cu, Mn and V) in the pericarp, pulp and seeds of the variant lines and the

parental line [32]. The five induced variant lines used in the previous study were also analysed for lycopene, total antioxidant properties and other quality factors such as pH, total soluble solids (TSS) and total solids. Similarly, 10 F5 tomato-breeding lines were characterized for variability in physico-chemical properties (colour, pH, total titratable acidity (TTA), TSS and vitamin C). The lines used include wosowoso (parent variety), cherry yellow, roma variant (a prolific trait), wosowoso variant (stripped, prolific and big fruit), roma variant (bicoloured fruit), *S. pimpinellifolium* parent, roma variant (hardened and big fruit), roma variant (yellow skin), roma variant (red skin) and wosowoso variant (big fruit, and deep red color). The lines varied in the various physico-chemical properties measured [33]. In addition, fruits of F4 lines derived from crosses between some varieties of *S. lycopersicon*, cherry red, cherry yellow and roma, and wosowoso with a wild tomato, *S. pimpinellifolium,* were analysed for physico-chemical properties, and variation was seen among the lines for the traits studied [34].

In 2014, five introduced fresh market tomato varieties from the USA and Crops Research Institute of Ghana (CRI) were evaluated for genetic variability, adaptability in Ghana as well as plant and fruit attributes. The varieties included Heinz, Shasta, Op-B149, Op-B155 and CRI-P00. With the advent of molecular markers, this study used 15 Simple Sequence Repeat (SSR) primers (**Table 1**) to determine the genetic diversity existing among the five introduced fresh market tomato varieties [35]. In order to establish the genetic diversity that exists in the germplasm collected in 2015, all the accessions (in exception of Rano) were evaluated in field as well as molecularly characterized using 12 SSR primers. The SSR primers include Tom 8–9-F, Tom 11–28-F, Tom 55–56-F, Tom 59–60-F, Tom 67–68-F together with seven primers listed in **Table 1** [36]. In the same year, 20 tomato genotypes were evaluated in the greenhouse as well as the field at the University of Ghana Forest and Horticultural Crops Research Centre (FOHCREC), Okumaning-Kade in the Eastern Region of Ghana to determine the genetic variability in agronomic and fruit-quality traits. There was variability in almost all the traits studied [37].

The various findings of the germplasm evaluation for morphological and agronomic traits together with the variability that exists in the germplasm can be explored in the development of new varieties.

3.2. Breeding for fruit quality

Cultivars such as OK, MH series [38] and Wosowoso [39] were developed in the 1950s. Agble [40] also began breeding for processing quality traits, shelf life and heat tolerance lines by making crosses between local accessions with heat-tolerant and nonripening gene (nor^{A}) from exotic accessions. Nonetheless, due to lack of continuity, no variety was released despite the positive outlook [41].

The NRI focused on pure line selection of local landraces in the Brong Ahafo region of Ghana with the aim of releasing pure lines of good open-pollinated varieties. Six varieties consisting of three local and three introduced varieties were used in that study. These varieties were selected based on farmers and traders (fruit quality, good taste and longer shelf life) preferred traits. As part of this project, a tomato breeder seed production trial was then established at Wa in the Upper West region with the five selected varieties. The research was, however, not very successful because there was no long-term impact due to lack of sustainable seed distribution systems to ensure that the resource-poor farmers have access to the developed varieties [42].

Marker no.	Primer sequence (5′-3′)	Number of bases
TGS0001F	GCGACCCTCTATTGAACTTGAAGAC (F)	25
	ACAAATCAAAGGAACAATTTCAA (R)	23
TGS0002F	GCAAACGTGTTCGAGTTCGTG (F)	21
	CCACACAATAAAGACAGAAAAATG (R)	24
TGS0003F	ATGCATGCGTGTGTGTTGTA (F)	20
	GTGTGTGTGTGTGTGTGTGT (R)	22
TGS0004F	GCAATTTATTTTCATTTGTTATACCGGA (F)	28
	ACCGAGACTCCTGGCTCATA (R)	20
TGS0005F	GACAAAAATTTTCCACACGGC (F)	21
	TCTCTTATAATTTTGTTGAGTCTCTGA (R)	27
TGS0006F	GTCGCATAAATATGGACAACGA (F)	22
	TTTTTAAAATACCATTCCAGAAAAA (R)	25
TGS0007F	GTGGATTCACTTACCGTTACAAGTT (F)	25
	CATTCGTGGCATGAGATCAA (R)	20
TGS0008F	GCGGTGTGAAATACAACAAGACG (F)	23
	CTCGACAAGCTAATTTCTGGG (R)	21
TGS0009F	GCGAAGCAAAAGAAAATTGGG (F)	21
	CACCACGAAGGCTGTTGTTA (R)	20
TGS0010F	TTGAAAAGCTGAAAAGTCAATCA (F)	23
	GAGAGGTGCCACATCACCTT (R)	20
TGS0012F	GTCCCTACCCCACAAATTGAA (F)	21
	AGGTACAACTCACCTCCCCC (R)	20
TGS0013F	GGTGGACATATGAGAAGACCTTG (F)	23
	TCATTTTCCAATGGTGTCAAA (R)	21
TGS0014F	GTGAAGACGAAAAACAAGACGA (F)	22
	CCTTCCCCTTTTGTCTCTCC (R)	20
TGS0020F	TCTTTCAACTTCTCAACTTTGGC (F)	23
	GCCGACTTCAAAAACTGCTC (R)	20
TGS0023F	GTCCAAATTAAAAACTAACCGCA (F)	23
	TTTCCAAAATGACCTAGCGG (R)	20

NB: F: forward primer, R: reverse primer.

Table 1. Tomato microsatellite markers used in DNA fingerprinting among five tomato accessions.

From 2011 to 2013, pure line selection was used to advance a locally identified cultivar commonly called petofake. From the segregating population collected from farmers, 12 progenies (P002, P005, P011, P020, P026, P035, P057, P068, P074, P077, P082 and P085) were selected based on their fruit shape, size, color, surface and yield [43]. Trials are ongoing to release these lines.

Dried seeds of SP 300/30.4.2.4, a variant line selected from second generation (M2) following the irradiation of *S. pimpinellifolium* at 300 Gy, were used for a study. Also, seeds (2000) of SP 300/30.4.2.4 were re-irradiated at 150 and 300 Gy and included in the study. From the study, it was found that the irradiation led to a reduction in plant height and a larger fruit size. Variation was also observed in color, plant height, architecture, number of days to flowering and fruiting. This variation can be explored in future breeding programmes [44].

3.3. Breeding for biotic stress

Post 2000 has seen some breeding efforts made in screening tomato accessions against biotic stresses. However, most of these programmes focussed on the most devastating tomato disease (TYLCD).

3.4. Screening germplasm for tomato yellow leaf curl disease resistance

TYLCD is a major tomato disease in Ghana and Africa as a whole and can lead to a massive yield loss and consequent impact on livelihood if the vector of the disease (whitefly) is not controlled and infection starts at an early stage of the plant growth [45]. The Tomato Yellow Leaf Curl Virus (TYLCV) causes the TYLCD. It was reported that the USAID West African Regional Programme identified research on Virus resistance (VR) as a priority, and Ghana was included in seven members' regional investigation of tomato virus complex [46]. The Agricultural Biotechnology Support Project II (ABSPII) aimed to improve agriculture production in the developing countries through Biotechnology, and that is why this project was initiated in 2005 to address tomato production in West Africa. This project was a partnership among researchers from AVRDC, Cornell University and University of California-Davis (UC Davis). The ABSII established the Regional Vegetable Germplasm Trailing Network that evaluated 100 putatively TYLCD-resistant tomato varieties that were adaptable to the growing conditions of West Africa which Ghana was a part from 2005 through 2008. In the 2005–2006 growing season, only 40 varieties were evaluated (**Table 2**). The resistant varieties used for the entire trial were mainly F1 hybrids since they were sourced from commercial seed companies and some breeding lines from breeding institutions. Based on the TYLCD scoring scale, at the end of the 2007–2008 multilocational trail, varieties such as Lety F1 scored below 1, Yosra scored 1, and Atak, Bybal and Gempride scored between 1.0 and 2.0 in Ghana (Navrongo and Technimanitia). The lower score was an indication of tolerance under the disease pressure. It was noted that the varieties suffered under farmers' field compared to research stations under comparable disease pressure. At the various trial locations, farmers preferred Lety F1, Yosra, Atak and Bybal. Due to the competitive nature of the tomato-breeding industry in developed world, some of the selected varieties were no longer in use in the countries where they were originally bred [47].

Seed source	Variety name	Resistance source
AVRDC	CLN 2123A Ty-2	Ty-2
	CLN 2460E Ty-2	Ty-2
	CLN 2468A Ty-2	Ty-2
	CLN 2498E Ty-2	Ty-2
	CLN 2545A Ty-2	Ty-2
	CLN 2545B Ty-2	Ty-2
	PT 4722A Ty-2	Ty-2
	TLCV 15 Ty-2	Ty-2
Cirad Guadeloupe	O4 108	
	O4 240	
	O4 495	
	O4 498	
	O4 501	
De Ruiter Seeds	Bybal	
	Industry DR 10403	
	Lety F1	
	Realeza	
	Thoriya	
Enza Zaden	Bybal	
	Industry DR 10403	
	Lety F1	
	Realeza	
	Thoriya	
Enza Zaden	Atak	
	Chenoa	
	Ponchita	
	Yosra	
Harris Moran	FTC 6231	*Ty-1*
	FTC 6236	*Ty-1*
	FTC 7088	*S. chilense* LA 1969, *S. habrochaites* H24
	FTC 7127	*Ty-2*, *S. habrochaites* H24
	FTC 7351	*S. chilense* LA 1969 and LA2779
	FTC 7483	*S. pimpinellifolium*
	HMX 4810	*S. chilense* LA 1969
Hazera	HA 3060	
Hebrew University	Favi 9	Ih902

Seed source	Variety name	Resistance source
Seminis	GemPride	*Ty-1*
	PS 43316	
Seminis—India	Sasya 0202 F1	
Syngenta	Cheyenne E448	
	Nirouz TH 99806	
	Yassamen TH 99802	
Takii	TY 75	*Ty-2*
Tropicasem	F1 3019 Galina	F1 3019 Galina
	Nadira	Nadira
	Roma VF	Susceptible check

Table 2. Forty varieties evaluated in 2005–2006 TYLCD resistance trails.

In 2008, three distinct isolates of the TYLCD virus were identified in Ghana from infected tomato plant samples collected from the Ashanti region in Ghana. The three strains of virus identified are the Tomato Yellow Leaf Curl Ghana Virus, Tomato Yellow Leaf Curl Kumasi Virus and the Tomato Yellow Leaf Curl Mali Virus [48].

Fifteen tomato accessions (collected from AVRDC-Taiwan and CSIR-Crops Research Institute, Ghana) that have been reported to be resistant to TYLCD as well as susceptible checks were screened against the TYLCD in a greenhouse at the Kwame Nkrumah University of Science and Technology (KNUST) in Kumasi (**Table 3**). These 15 accessions were later on evaluated in the field at Afari (hot spot) in the Ashanti region. The whiteflies used for the greenhouse inoculation were collected from infested tomato plants at Akumadan, Agogo and Afari. The incidence and severity of TYLCV were scored 30, 45 and 60 days after transplanting using the severity scale 0–4 developed by Lapidot and Friedmann in 2002. At 60 days after transplanting in the greenhouse, accessions A2 (FLA456-4), G14 (WSP2F7 (3) PT.3) and G15 (WSP27F7 (3) PT.3) expressed moderate symptoms in terms of incidence of the TYLCD while accessions A8 (99S-C-39-20), A9 (H24), G13 (WS273.3LARGE) and G12 (WSP2F1PT.3) also showed mild symptom of the disease. A1 (TY52), A3 (FLA478-6-3-0), A6 (TLB111) and A7 (LA 1969) expressed slight severity to the TYLCD. Accessions G11 (PIMPILIFOLIUM) and A1 (FLA505) had the lowest incidence rate compared to accessions A10 (CLN2026D), G13 (WS273.3LARGE) and A4 (FLA653-3-1-0) that had the highest incidence of TYLCV infection in the field. At 60 days after transplanting only accession, A1 (FLA505) showed no TYLCD symptoms [49].

Again, 30 accessions (including the 15 accessions that were screened in the greenhouse and the field in 2010) were screened against the local strains of virus in Afari in the Ashanti region (**Table 4**). Some of these accessions were reported to be resistant in other countries. Only two accessions (Local Rano and Petomech-Ghana/France) out of the 30 accessions expressed mild symptoms whilst accessions WSP2F1pt.3 and Tomato Red Cloud expressed moderate symptoms after 60 days of transplanting. In order to confirm the resistance or susceptibility

Accessions	Resistance source	Origin
TY52 (A7)	LA 1969	D. Zamir, Hebrew University
'FLA456–4 (A2)	Tyking, LA2779 (*L. chilense*)	J. Scott, University of Florida
FLA505 (A1)	LA1969, Tyking, Fiona	J. Scott, University of Florida
FLA496–11–6-1-0 (A5)	LA1932	J. Scott, University of Florida
FLA478–6–3-0 (A3)	LA1938 (*L. chilense*), Tyking	J. Scott, University of Florida
FLA653–3–1-0 (A4)	LA2779 (*L. chilense*), Tyking	J. Scott, University of Florida
99S-C-39-20 (A8)	Unknown	Namdhari Seeds, India
H24 (A9)	*L. hirsutum* f.sp. *glabratum*	G. Kalloo, India
TLB111 (A6)	H24	AVRDC
CLN2026D (A10)	Susceptible check	AVRDC
WSP2F1PT.3 (G12)	Unknown	CSIR-CRI
WS273.3LARGE (G13)	Unknown	CSIR-CRI
WSP2F7 (3) PT.3 (G14)	Unknown	CSIR-CRI
PIMPILIFOLIUM (G11)	Unknown	CSIR-CRI
WSP27F7 (3) PT.3 (G15)	Susceptible Check	CSIR-CRI

Table 3. Tomato accessions used for the TYLCD screening in both the greenhouse and the field.

observed in the field, six viral detection primers were used to screen all the 30 tomato accessions (**Table 5**). From the results obtained in that study, none of the primers amplified viral DNA in Tomato Red Cloud. For WSP2F1pt.3, only one of the six primers (PAL/PAR) amplified the viral DNA. Only MF/MR primer amplified the viral DNA in Local Roma. For Petomech (Ghana/France), two primers (GHF/GHR and KR/KF) amplified the viral DNA. None of the 30 accessions was considered resistant since none of them showed no symptom in the field as well as no TYLCV DNA amplification [50].

Again, between 2010 and 2011, seven tomato varieties (**Table 6**) were grown in the fields against the TYLCD in the University of Ghana and the Volta region of Ghana. The symptom expression of the varieties against the TYLCV was confirmed in the laboratory using the set of primers in **Table 5** in addition to Beta 01/02. The study also identified Ty-3 gene in tomato that confer resistance to TYLCV using the primers in **Table 7**. From the field screening, it was found that Burkina (obtained from farmers in the Volta region) had the highest TYLCD incidence, followed by Petomech and the susceptible check. However, Petomech expressed higher severity than Burkina. Both severity and incidence were lower in the hybrids in exception of F1 Thorgal that showed no symptom. AC1048/AV494 detected the most viral DNA in the samples collected. The primer set T0302-F/T0302-R did not amplify the Ty-2 gene in any of the varieties evaluated. However, Primer P6-25-F/P6-25-R amplified a band size of approximately 400 bp in F1 Jaquar, F1 Nadira and *S. pimpinellifolium* [51].

Entries	Code	Resistance source	Origin
FLA 505	A1	LA 1969 (*L. chilense*)	J. Scott, Univ. Florida
FLA 456–4	A2	Tyking, LA2779 (*L. chilense*)	J. Scott, Univ. Florida
FLA 478–6–3-0	A3	LA1938, Tyking, Fiona	J. Scott, Univ. Florida
FLA 653–3–1-0	A4	LA2779 (*L. chilense*), Tyking	J. Scott, Univ. Florida
FLA 496–11–6-1-0	A5	LA1932 (*L. chilense*), Tyking	J. Scott, Univ. Florida
TLB 111	A6	H24	AVRDC
TY52	A7	LA 1969 (*L. chilense*)	D. Zamir, Hebrew Univ.
99S-C-39-20-11-24-17-0	A8	Unknown	Namdhari Seeds, India
H24	A9	*L. hirsutum* f.sp. *glabratum*	G. Kallo, India
CLN2026D	A10	Susceptible check	AVRDC
Pimpinellifolium	G11	Unknown	CSIR-CRI
WSP2F1pt.3	G12	Unknown	CSIR-CRI
WS273.3 Large	G13	Unknown	CSIR-CRI
WSP2F7 (3) pt.3	G14	Unknown	CSIR-CRI
2641A	B16	Unknown	AVRDC
Tomato Money Maker	B17	Unknown	USA
Tomato Roma-Jam Vf	B18	Unknown	Burkina Faso
Parona	B19	Unknown	Local
Local Roma	B20	Unknown	Local
Rando	B21	Unknown	Local
Tomato Slumac	B22	Unknown	Holland
Tomato Tima	B23	Unknown	France
Tomato Red Cloud	B24	Unknown	Holland
Tomato Rio Grande	B25	Unknown	Holland
Petomech (Ghana/France)	B26	Unknown	France
Tomato Roma VF	B27	Unknown	USA
Petomech (Ghana/Burkina)	B28	Unknown	Burkina Faso
Petomech (Ghana)	B29	Unknown	Ghana
Tomato Ventura F	B30	Unknown	USA

Table 4. A list of tomato accessions screened against the tomato yellow leaf curl disease in Afari.

Between 2011 and 2012, a group of researchers also evaluated the susceptibility of 10 accessions to TYLCD under field conditions. The accessions include *S. pimpinellifolium*, Wosowoso, Cherry red, Roma, Hyb−1 (Wosowoso × *S. pimpinellifolium*), Hyb-2 (Roma × *S. pimpinellifolium*), Hyb-3

Marker name	Primer sequence	Source
PARc1496/PAL1v1978	F:5′GCATCTGCAGGCCCACATYGTCTTYCCNGT R: 5′AATACTGCAGGGCTTCTRTACATRGG	Rojas et al. (1993)
AV494/AC1048	F: GCCCATGTATAGAAAGCCAAG R: GGATTAGAGGCATGTGTACATG	Wyatt and Brown (1996)
PTYv787/PTYc1121	F: 5-GTTCGATAATGAGCCCAG-3 R: 5-ATGTAACAGAAACTCATG-3	Zhou et al. (2008)
GHF/GHR	F: GCCCGAAAGCTTCGTTGTT TTCCCGCT R: ACGGATGGCCGCTTTGGGT ATTCG	Osei et al. [48]
KF/KR	F: GGACCCGGCGCACTATTTAT GTTGGC R: ACCCCATTACCCCAATACCA	Osei et al. [48]
MF/MR	F:TGGCCGCGCCCTTCCTTTTGT R: ACCAATGGCTCCCCAAAGCGT	Osei et al. [48]

NB: F: Forward primer, R: Reverse primer.

Table 5. A list of primers used in TYLCV DNA detection.

(Cherry red × *S. pimpinellifolium*), BC-1 (Wosowoso × (Wosowoso × *S. pimpinellifolium*)), BC-2 (Roma × (Roma × *S. pimpinellifolium*)) and BC-3 (C-Red x (C-red × *S. pimpinellifolium*)). The observed TYLCD symptoms on *S. pimpinellifolium* were no visible symptom to slight yellowing of margins of apical leaflets.

The observed symptoms on the hybrids together with the backcrosses were slight yellowing of margins of apical leaflets and moderate yellowing and slight curling of leaflet tips. The results from the phenotypic screening were verified with a molecular marker detection of

Varieties	Resistance	Source
F1 Jaguar	TYLCV	Technisem (AgriSeed Company Ltd.)
F1 Nadira	TYLCV	Technisem (AgriSeed Company Ltd.)
F1 Thorgal	TYLCV	Technisem (AgriSeed Company Ltd.)
Petomech	Unknown	University of Ghana
Burkina	Unknown	Farmer variety
Solanum pimpinellifolim	Reported resistance to TYLCV	Farmers
CLN2026D	Susceptible check	AVRDC

Table 6. Tomato germplasm used for field screening against TYLCD in Volta region and University of Ghana.

Primer	Primer sequence	Reference
T0302-F/T0302-R	F: TGGCTCATCCTGAAGCTGATAGCGC	Ji and Scott (2006)
	R: AGTGTACATCCTTGCCATTGACT	
P6–25-F/P6–25-R	F: GGT AGT GGA AAT GAT GCTGCTC	Ji et al. (2007)
	R: GCT CTG CCT ATT GTC CCA TAT ATA ACC	

Table 7. Primer pairs and sequences for TYLCV gene detection.

the viral DNA among the accessions. This work also deployed both triple antibody sandwich enzyme-linked immunosorbent assay (TAS-ELISA) and PCR method (using the primers in **Table 5**) for the TYLCV detection in order to recommend a better way of detecting TYLCV in infected samples. A TAS-ELISA kit with a known TYLCV-infected *Nicotiana benthamiana*-positive control was used for the study. The study confirmed the superior sensitivity of the PCR technique as a TYLCV detection method compared to the TAS-ELISA technique. There were no observable TYLCV symptoms on the BC-3 (C-Red × (C-red × *S. pimpinellifolium*)) in the field and both methods did not detect viral DNA in the leaf samples. BC- 1 (Wosowoso × (Wosowoso × *S. pimpinellifolium*)) behaved similarly like BC-3 in the field but there was amplification of viral DNA by the AV494/AC1048 primer set. In addition, two PCR primers detected viral DNA in the *S. pimpinellifolium* even though there was no TYLCV symptom observed in the field.

Recently, there was a phenotypic evaluation of 36 local tomato genotypes (**Table 8**) for the source of resistance against TYLCD in two locations (University of Cape Coast and Asuansi) in Ghana. The results showed that five accessions (K005-Petomec, K100-Local 3, K213-AVTO 9804, K116-Ashanti 2 and K042-Tomatose) out of the 36 genotypes were selected for mild severity, two genotypes showed severe symptoms (K027-Local, K202-AVTO 0102) and one genotype (LV-Fadzebegye) showed moderate severity. In order to confirm the infection or otherwise of the eight tomato accessions selected for mild and severe symptom expression, two of the viral detection primers (AV494/AC1048 and PTYv787/PTYc1121) were used for the detection of the virus in infected plant samples (**Table 5**). The primer pair AV494/AC1048 amplified the viral DNA in all the eight genotypes (K100, K027, K116, K005, K202, LV, K213 and K042) in the University of Cape Coast and six out of the eight genotypes in Asuansi (K100, K027, K116, K005, K202 and K042) (**Table 8**). The primer pair PTYv787/PTYc1121 on the other hand amplified viral DNA in all the samples from both locations [53].

3.5. Molecular screening of tomato germplasm for root knot nematodes resistance

This study involved the use of primer Mi23/F//Mi23/R to detect the presence or absence of *Mi* genes in twenty eight (28) tomato cultivars (**Table 9**). The primer amplified the homozygous resistant genotypes (*Mi*/*Mi*) in cultivars VFNT, FLA 505-BL 1172, 2641A, "Adwoa Deede" and Terminator FI while the heterozygous resistant genotypes (*Mi*/*mi*) were amplified in cultivars Tima and 2644A [54].

Codes	Genotype names	Source
K116	Ashanti 2	Ghana (Ashanti region)
K045	Tomatose	Ghana (Volta region)
K042	Tomatose	Ghana (Volta region)
K100	Local 3	Ghana (Upper East)
K074	Local 6	Ghana (Northern region)
K144	BK-Dotvert Yako	Burkina Faso (Burkina Faso)
K124	Local 1	Ghana (Ashanti region)
K005	Petomec	Ghana (Eastern region)
K214	AVTO 9001	Taiwan(AVRDC)
K138	BK-Koly zy	Burkina Faso
K146	BK-Kong-L6	Burkina Faso
K194	Magmet	Korea
K087	5(K)	Ghana (SARI)
K084	1R	Ghana (SARI)
K188	Madiso	Korea
K027	Local	Ghana (Volta region)
K098	Local 1	Ghana
K088	Local1	Ghana (Upper East)
K205A	AVTO 1006	Taiwan (AVRDC)
K197	REX	Ghana (Eastern region)
P077	Local 9	Ghana (Northern region)
K213	AVTO 9804	Taiwan (AVRDC
K083	6(A)	Ghana (SARI)
K050	Asante tomato	Ghana (Western region)
K011	Ntose	Ghana (Eastern region)
K106	Local 2	Ghana (Upper East)
P085	21(B)	Ghana (SARI)
K200	2001 heat tolerant	Ghana (Eastern region)
K191	Dyune	Korea
K186	Superdotaerang	Korea
K190	Orange carl	Korea
K006	Power Rano	Ghana (Eastern region)
K202	AVTO 0102	Taiwan (AVRDC)
P009	Mmoboboye	Ghana (Eastern region)
K206	AVTO 1008	Taiwan (AVRDC)
L.V	Fadzebegye	Ghana (Central region)

Table 8. Code, name and sources of 36 tomato genotypes screened against TYLCD.

Cultivar	Source/origin
FLA 505-BL1172	AVRDC, Taiwan
2641A	AVRDC, Taiwan
Wosowoso	Commercial, Ghana
FLA 496–11–6-0	AVRDC, Taiwan
Adwoa Deede	Commercial, Ghana
TLB111	AVRDC, Taiwan
Terminator F1	Green seeds, India
3008A	AVRDC, Taiwan
Roma-JAM VF	Commercial, USA
Burkina Petomech	Commercial, France
Roma VF	Commercial, B. Faso
Ventura F	Commercial, France
Slumac	Commercial, Holland
Red	Commercial, Holland
Rando	Commercial, Ghana
Akoma	Commercial, Ghana
Ghana Petomech	Petomech Commercial, France
Floradade	Commercial, USA
FLA 478–6–3-0	AVRDC, Taiwan
Money maker	Comm. South Africa
Tima	Commercial, France
Rio grande	Commercial, Holland
Parona	Commercial, Ghana
Biemso	Commercial, Ghana
Power	Commercial, Ghana
2644A	AVRDC, Taiwan
VFNT (Resist. check) TGRC, V. Williamson	VFNT (Resist. check) TGRC, V. Williamson
UC82 (Suscept. check) TGRC, V. Williamson	UC82 (Suscept. check) TGRC, V. Williamson

Table 9. Tomato cultivars evaluated for nematode resistance.

3.6. Screening for abiotic stress

Another important tomato-breeding objective is breeding for abiotic stress; nonetheless, there is limited published work on screening of tomato against abiotic stresses in Ghana. It was reported that 19 tomato cultivars (**Table 10**) were screened for adaptation to high temperature,

Tomato cultivar	Origin
'Petomech'	Monarch Seed, Holland
'Rio Grande VF'	Griffaton Producteur Grainier, France
Tomato Rockstone VF'	Griffaton Producteur Grainier, France
'Caracoli'	Griffaton Producteur Grainier, France
F1 Ninja'	Technisem, France
'Tropimech'	Technisem, France
'Petomech VF II	Improved Petoseed Seminis, Netherlands
'Moneymaker'	Griffaton Producteur Grainier, France
King 5'	Japan
Queen'	Japan
'18I (CLN 2318 F)'	AVDRC
14IR Island Red'	Samoa Island
'8S Selected SM1'	Samoa Island
'5C Roma'	Samoa Island
'17I (CLN 2443B)'	AVDRC
'Nkansah'	Forest and Horticulture Crops Research Centre, Kade, University of Ghana
'DV-2962'	Seminis Monsanto, Thailand
'Champion'	Crop Science Department, University of Ghana
Wosowoso'	Crop Science Department, University of Ghana

Table 10. Tomato cultivars used for the heat stress.

and it was found that Nkansah, King 5, 181 (CLN 2318 F) and DV 2962 cultivars were better adapted to heat stress [55].

The outcome of these various screening programmes can be utilized in a hybridization programme by crossing genotypes expressing mild symptoms to the TYLCV and nematodes as well as genotypes that are tolerant to heat with locally adapted accessions that are susceptible to these stresses to develop resilient varieties.

3.7. Potential tomato breeding objectives

Tomato varieties currently grown in Ghana are generally acidic, watery, poor in color, poor shelf life and susceptible to TYLCV as well as intolerant to heat. Future tomato-breeding programmes should focus in the short-term on introgression of Tomato Yellow Leaf Curl Disease Resistant genes into locally adapted varieties and improving the shelf life of these locally adapted tomato varieties. These will address the major constraints facing the tomato industry in Ghana. Long-term tomato-breeding objectives should encompass the improvement of fruit color, increasing brix, improving rainy season varieties with good fruit-quality traits, increasing variability through

irradiation, resistance to other biotic and abiotic stresses as well as sensory and nutritional value. Due to the pressing nature of these short-term breeding objectives, students of the West Africa Centre for Crop Improvements (WACCI), University of Ghana, are currently breeding for TYLCD-resistant varieties and prolonged tomato shelf life. Other students of the same institution are also working on breeding for processing quality and Bacteria Wilt-resistant tomato varieties.

4. Conclusion

Tomato is indispensable in all Ghanaian recipes and contributes significantly to the economy of Ghana. Ghana has the potential to meet the country's tomato demand; however, low yield, unavailability of quality tomato varieties, pests and diseases have hindered this potential. This review presented tomato production trends in Ghana, past tomato-breeding programmes that have been carried out as well as some potential tomato-breeding objectives. Ghana will achieve self-sufficiency in tomato production if the government, Universities, Research Centres and National Research Institute (NRI) will invest more resources into tomato breeding to achieve both the short- and long-term-breeding objectives. This review will serve as a reference for improving tomato in the country.

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References

[1] Knapp S. Tobacco to tomatoes: A phylogenetic perspective on fruit diversity in the Solanaceae. Journal of Experimental Botany. 2002 Oct 1;**53**(377):2001-2022

[2] Peralta IE, Spooner D. History, origin and early cultivation of tomato (Solanaceae). Genetic improvement of Solanaceous crops. In: Razdan MK, Mattoo AK, editors. Genetic Improvement of Solanaceous crops. Vol. 2. Enfield. Nueva Hampshire: Science Publishers; 2007. pp. 1-27

[3] Larry R, Joanne L, Razdan MK, Mattoo AK. Genetic Resources of Tomato Genetic Improvement of Solanaceous Crops, Vol. 2. Enfield: NH Science Publishers; 2007

[4] Soyk S, Lemmon ZH, Oved M, Fisher J, Liberatore KL, Park SJ, Goren A, Jiang K, Ramos A, van der Knaap E, Van Eck J, Zamir D, Eshed Y, Lippman ZB. Bypassing negative epistasis on yield in tomato imposed by a domestication gene. Cell. 2017;**169**:1-14. DOI: 10.1016/j.cell.2017.04.032

[5] Kimura S, Sinha N. Tomato (*Solanum lycopersicum*): A model fruit-bearing crop. Cold Spring Harbor Protocols. 2008. DOI: 10.1101/pdb.emo105

[6] Wilcox JK, Catignani GL, Lazarus C. Tomatoes and cardiovascular health. Critical Reviews in Food Science and Nutrition. 2003;**43**(1):1-18

[7] FAOSTATS. 2013. http://www.fao.org/faostat/en/#data/QC (Accessed: 2017-10-2)

[8] FAOSTATS 2014; http://www.fao.org/faostat/en/#data/QC (Accessed: 2017-10-2)

[9] Norman JC. Tropical Vegetable Crops. Pub.Arthur Stock Well Ltd. 1992. pp. 15-53

[10] Gongolee GAK. Evaluation of Some Introduced Fresh Market Tomato (*Solanum lycopersicum* L) for Genetic Variability and Adaptability in Ghana using Morphological and Molecular Markers. University of Ghana; 2014

[11] Schippers RR. African Indigenous Vegetables. An Overview of the Cultivated Species. London, UK: Natural Resources Institute; 2000. 222 pp. ISBN 0 85954 515 6

[12] FAOSTATS. 2013; http://www.fao.org/faostat/en/#data/QC (Accessed: 2017-10-2)

[13] FAOSTATS. 2014; http://www.fao.org/faostat/en/#data/QC (Accessed: 2017-10-2)

[14] Osei MK, Offei Bonsu K, Asare C, Agyeman A, Gyau J, Choi HS. Germplasm collections: a prerequisite for tomato breeding programme in Ghana. Advanced Crop Science. 2013;**3**(9):568-578

[15] Sunil Kumar SV. Plant breeding and its goals. Biotech articles. 2012; https://www.biotecharticles.com/Agriculture-Article/Plant-Breading-and-its-Goals-1318.html

[16] Ghana Imports Vegetable too! United Nations Commodity Trade Statistics Database. Ghana Web Business News. 2014. https://www.ghanaweb.com/GhanaHomePage/NewsArchive/artikel.php?ID=317686

[17] Robinson EJ, Kolavalli SL. The Case of Tomato in Ghana: Institutional Support. International Food Policy Research Institute (IFPRI; 2010)

[18] Horna D, Smale M, Al-Hassan R, Falck-Zepeda, Timpo SE. Insecticide Use on Vegetables in Ghana. Would GM seed Benefit Farmers? IFPRI Discussion paper. 2008; 00785

[19] Robinson EJ, Kolavalli SL. The case of tomato in Ghana: Productivity. International Food Policy Research Institute (IFPRI); 2010

[20] Tweneboah CK. Vegetable and Spices in West Africa. North Dwowulu: Kodua Ville; 1998

[21] Horna D, Smale M, Al-Hassan R, Falck-Zepeda, Timpo SE. Insecticide Use on Vegetables in Ghana. Would GM seed Benefit Farmers? IFPRI Discussion Paper. 2008; 00785

[22] Duodo F. Tomato Disease Attacks Farms in Agotime-Ziope. Business and Finance, Business Guide. 2014; https://www.modernghana.com/news/555472/tomato-disease-attacks-farms-in-agotime-ziope.html [Accessed: 2017-09-20]

[23] Horna, Smale D, Falck-Zepeda MJ. Assessing the potential economic impact of genetically modified crops in Ghana: Tomato, Garden Egg, Cabbage and Cassava. PBS Report. Available upon request (dhorna@cgiar.org). International Food Policy Research Institute; 2006

[24] Osei MK, Akromah R, Shih SL, Green SK. Evaluation of some tomato germplasm for resistance to *Tomato yellow leaf curl virus* (TYLCV) disease in Ghana. Applied Biology. 2010:**96**:315-323

[25] Kugblenu YO, Oppong Danso E, Ofori K, Andersen MN, Abenney-Mickson S, Sabi EB. Screening tomato genotypes for adaptation to high temperature in West Africa. Acta Agriculturae Scandinavica, Section B - Soil & Plant Science. 2013 Sep;**63**(6):516-522. DOI: 10.1080/09064710.2013.813062

[26] Robinson EJ, Kolavalli SL. The Case of Tomato in Ghana: Institutional Support. International Food Policy Research Institute (IFPRI); 2010

[27] Osei MK, Akromah R, Shih SL, Green SK. Evaluation of some tomato germplasm for resistance to *Tomato yellow leaf curl virus* (TYLCV) disease in Ghana. Applied Biology. 2010:96

[28] Osei MK, Offei Bonsu K, Asare C, Agyeman A, Gyau J, Choi HS. Germplasm collections: A prerequisite for tomato breeding programme in Ghana. Advanced Crop Science. 2013;**3**(9):568-578

[29] Opoku JA. Genetic Variability in Tomato Germplasm (*Solanum lycopersicum* L.) using Morphological Characteristics and Simple Sequence Repeat (SSR) Markers. Kwame Nkrumah University of Science and Technology (KNUST); 2015

[30] Vegetable Breeding, Major Achievement and Progress Made. Council for Scientific and Industrial Research – Savanna Agriculture Research Institute; 2002

[31] On Station Evaluation of Tomato Genotypes. Council for Scientific and Industrial Research–Savanna Agriculture Research Institute; 2013

[32] Quartey KE, Opata SN, Amoatey HM, Klu GYP. Elemental composition in fruits of gamma-radiation induced variant lines of *Solanum pimpinellifolium* L. Nuclear Agriculture Centre, Biotechnology and Nuclear Agriculture Research Institute, Ghana. Asian Journal of Agricultural Sciences. 2012;**4**(3):198-204 ISSN: 2041-3890

[33] Nunoo J, Ofori ESK, Quartey KE, Gasu EK, Ewusie EA, Odai TA, Torgby-Tetteh W, Agbemavor WSK. Characterization of some physico-chemical properties of F5 breeding lines of tomatoes. British Journal of Applied Science & Technology. 2014;**4**(27):3967-3975

[34] Agbemavor WSK, Torgby-Tetteh W, Quartey EK, Nunoo J, Nunekpeku W, Owureku-Asare M, Agyei-Amponsah J, Apatey J. Physico-chemical evaluation of fruits from the fourth filial generation of some breeding lines of tomatoes. International Journal of Nutrition and Food Sciences. 2014;**3**(4):318-325. DOI: 10.11648/j.ijnfs.20140304.23

[35] Gongolee GAK. Evaluation of some introduced fresh market tomato (*Solanum lycopersicum* L) for genetic variability and adaptability in Ghana using morphological and molecular markers. Kwame Nkrumah University of Science and Technology (KNUST); 2014

[36] Opoku JA. Genetic Variability in Tomato Germplasm (*Solanum lycopersicum* L.) using Morphological Characteristics and Simple Sequence Repeat (SSR) Markers. Kwame Nkrumah University of Science and Technology (KNUST); 2015

[37] Ochar K. Studies on Genetic Variability in Agronomic and Fruit Quality Traits among Some Tomato (*Solanum lycopersicum* L.) Genotypes. University of Ghana; 2015

[38] McEwen J. Review of work on tomatoes. Ghana Farmer. 1961;**IV**(3)

[39] Shippers RR. African Indigenous Vegetables. An Overview of the Cultivated Species. London, UK: Natural Resources Institute; 2000. 222 pp. ISBN 0 85954 515 6

[40] Agble F. Crop Research Institute Horticulture Division Annual Report. 1978. pp. 8-13. Hort/12/SF2/Vol

[41] Orchard JE, Suglo EK. Integrated food crops systems projects: enhancing smallholder livelihood through reducing costs and adding value to agricultural production. Final Technical Report. City; 1999

[42] Robinson EJ, Kolavalli SL. The Case of Tomato in Ghana: Institutional Support. International Food Policy Research Institute (IFPRI); 2010

[43] Osei MK, Bonsu KO, Adu Gyamfi K, Frimpong M. Development of high yielding and uniform tomato fruits using pure line selection. Direct Research Journal of Agriculture and Food Science (DRJAFS). 2015;**3**(1):10-16. Directresearchpublisher.org/drjafs

[44] Nunoo J, Quartey EK, Amoatey HM, Klu GYP. Effect of recurrent irradiation on the improvement of a variant line of wild tomato (*Solanum pimpinellifolium*). Journal of Radiation Research and Applied Sciences. 2014;**7**:377-383. DOI: 10.1016/j.jrras.2014.07.007

[45] Osei MK, Akromah R, Lamptey RJNL, Quain MD. Phenotypic and molecular screening of some tomato germplasm for resistance to tomato yellow leaf curl virus disease in Ghana. African Journal of Agricultural Research. 2012;**7**(33):4675-4684. DOI: 10.5897/AJAR12.672

[46] Horna D, Smale M, Falck-Zepeda J. Assessing the Potential Economic Impact of Genetically Modified Crops in Ghana: Tomato, Garden Egg, Cabbage and Cassava. PBS Report. International Food Policy Research Institute; 2006. Available upon request (dhorna@cgiar.org)

[47] Gordon J. Reseeding Tomato Production in West Africa: Identification and Deployment of High Yielding Cultivars Resistant to Tomato Yellow Leaf Curl Disease. Faculty of the Graduate School of Cornell University; 2009

[48] Osei MK, Akromah R, Shih SL, Lee LM, Green SK. First report and molecular characterization of DNA A of three distinct begomoviruses associated with tomato leaf curl disease in Ghana. Plant Disease. 2008;**92**(11):1585-1585. http://apsjournals.apsnet.org/doi/abs/10.1094/PDIS-92-11-1585B

[49] Osei MK, Akromah R, Shih SL, Green SK. Evaluation of some tomato germplasm for resistance to *Tomato yellow leaf curl virus* (TYLCV) disease in Ghana. Applied Biology. 2010;**96**:315-323

[50] Osei MK, Akromah R, Lamptey RJNL, Quain MD. Phenotypic and molecular screening of some tomato germplasm for resistance to tomato yellow leaf curl virus disease in Ghana. African Journal of Agricultural Research. 2012;**7**(33):4675-4684. DOI: 10.5897/AJAR12.672

[51] Ossom M. Etiology and Management of Leaf Curl Disease in Volta Region in Ghana. University of Ghana; 2012

[52] Segbefia MM, Amoatey HM, Quartey EK, Ahiakpa JK, Appiah AS, Nunoo J, Kusi-Adjei R. Detection of TYLCV in ten genotypes of tomato (*Solanum* spp L.) using serological and molecular techniques in a coastal savanna zone of Ghana. Journal of Natural Sciences Research. 2015;**5**(2):2224-3186. ISSN: 2225-0921

[53] Asare-Bediako E, Wonkyi DM, Van der Puije G, Amenorpe G, Osei MK. Variation in the susceptibility of tomato (*Lycopersicon solanum* L.) genotypes to tomato yellow leaf curl virus (TYLCVD) infections at coastal savannah and forest zones of Ghana. Australian Journal of Crop Science. 2017;**11**(04):373-381. DOI: 10.21475/ajcs.17.11.04.pne124

[54] Danso Y, Akromah R, Osei K. Molecular marker screening of tomato (*Solanum lycopersicum* L.) Germplasm for root-knot nematodes (*Meloidogyne* species) resistance. African Journal of Biotechnology. 2011;**10**(9):1511-1515

[55] Kugblenu YO, Oppong Danso E, Ofori K, Andersen MN, Abenney-Mickson S, Sabi EB. Screening tomato genotypes for adaptation to high temperature in West Africa. Acta Agriculturae Scandinavica, Section B - Soil & Plant Science. 2013 Sep;**63**(6):516-522. DOI: 10.1080/09064710.2013.81306

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