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Research Article

Tomato Production and Associated Stress: a Case of African Climate

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ABSTRACT

Tomato is an economically important crop by reason of it being the second horticultural crop produced in terms of yield and consumption globally. Aside its health benefits, tomato has become a commodity of pride amongst vegetarians as well as non-vegetarians due to its wide variety of usage, both domestically and industrially. This wide usage has conferred great importance and increased global demand all year round hence creating a large market, both locally and internationally. However, there are a number of constraints associated with tomato production but the most significant are biotic and abiotic stress whose expressions and severity varies across the growing climates around the world. The tropical and sub-tropical climates of Africa are amongst the notable growing zones with Egypt (North Africa) and Nigeria (West Africa) holding the 5th and 10th position respectively on the global production output (tonnes). The summation of production output from Egypt and Nigeria surpasses that from the remainin g countries thus making the duo key potential production zones for delivery of scientific innovation in improving tomato production per unit area within the African climate.

Keywords: Tomato, Biotic stress, Abiotic stress, Genetic improvement

INTRODUCTION

Tomato (Solanum lycopersicum L.) is a popular and economically important crop plants around the world. The second largest vegetable both in terms of production and consumption [1]. It ranks 7th in worldwide production after wheat, rice, maize, potatoes, soybeans and cassava, reaching a worldwide production of around 170 million tonnes on a cultivated area of almost 5.2 million hectares in 2018 [2]. It has gained popularity in recent times with the discovery of health benefits inherent in the valuable compound, lycopene, which possesses anti-oxidative and anticancer properties [3, 4]. Lycopene in tomatoes enhance fertility by improving the quality and swimming speed of sperm whilst reducing the number of abnormal sperm in men [5, 6]. Alongside other nutrients, tomato fruit contains beta-carotene, flavonoids, vitamin C and phenolic compounds, which offer many health benefits for the consumers [7]. Despite all the numerous benefits from the crop, many challenges are making its production unprofitable in most developing countries especially those in Africa. The challenges faced by producers can either be in production, post-harvest, marketing or a combination of any of them. Global tomato production increased during the 1920s as a result of breakthroughs in technologies that made mechanized processing possible [8]. With increasing knowledge in benefits derived from genetic modification of tomatoes, more desirable parameters have been selected for varietal improvement to enhance the crop for human consumption thus creating a continued increase in tomato production and consumption [4].

Crops grown in open fields encounter multiple unfavorable conditions for optimal plant growth and yield, of both abiotic and biotic origin. According to [9], some biotic and abiotic factors have been attributed to low yields and the increased cost of production. The low diversity among commercial tomato varieties has been identified as one of the major factors that predispose the crop to biotic and abiotic constraints [10]. Poor soil fertility [11], extreme heat and insufficient or unpredictable water supply [12], which have hitherto become prevalent in the wake of a changing climate [13]. Biotic stress creates additional losses, with newly emerging plant diseases and pests causing decreased yields and serious reductions in produce quality. In West Africa, tomato growers are faced with a number of disease and pest problems. Soil-borne diseases include bacterial wilt

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caused by Ralstonia solanacearum and Fusarium wilt caused by Fusarium oxysporum f. sp. lycopersici; foliar diseases include bacteria spot caused by Xanthomonas spp., late blight caused by Phytophthora infestans and Septoria blight caused by Septoria lycopersici; and mosaic viruses, such as Tomato mosaic virus and Cucumber mosaic virus, can cause yield loss and produce damage. Pests include worms, such as the cotton bollworm (Helicoverpa armigera), nematodes, mining insects, thrips, various aphid species, and mites, e.g., spider mites (Tetranychus urticae). Recently, outbreaks of the tomato leaf miner ((Tuta absoluta (Meyrick) (Lepidoptera: Gelechiidae)) have caused substantial damage to tomato crops in some West Africa countries [14 – 16]. Therefore, this substantiate the need to review the production output of tomato in the African production zones with a view to visualize the effect of associated stress and potential remedy backed by scientific research.

TOMATO PRODUCTION OUTPUT INDEX

Tomato is produced in temperate, subtropical and tropical areas around the world [17] and it is the second horticultural crop produced in terms of yield in the world [1]. Numbers from 2014 showed China, India, United States, Turkey and Egypt as the countries with the largest production area [1, 18]. There has been a steady increase in the production output (Table 1) in China, India, USA, and Turkey whereas the reverse is obtainable in Egypt, where there is a steady decline in the production output over the period under review (2014 – 2018). Although there is a steady increase in the global cumulative production output year-on-year however, the variations in the production output across the producing countries over the period signals the presence of attendant challenges associated with production – prominent amongst others are biotic and abiotic stress gaining ground with the changing climate. The outbreak of tomato Ebola and Tuta absoluta in Nigeria [16] could have contributed to the significant drop in production output in 2016.

Country	2014	2015	2016	2017	2018
China	52803743	55813808	57571895	59599343	61631581
India	18735910	16385000	18732000	20708000	19377000
USA	15875000	14580440	12877049	11141862	12612139
Turkey	11850000	12615000	12600000	12750000	12150000
Egypt	8288043	7737827	7320714	6729004	6624733
Iran	6362902	6013142	5828557	6234717	6577109
Italy	5624245	6410249	6437572	6015868	5798103
Spain	4888880	4832700	5233542	5163466	4768595
Brazil	4302777	4187729	4166789	4225414	4110242
Nigeria	4083500	4229330	3412650	4100000	3913993
Mexico	3536305	3782314	4047171	4243058	4559375
Russia	2819193	2840534	2335772	2668993	2899664
Uzbekistan	2285801	2562337	2796189	2455125	2284217
Ukraine	2147880	2274410	2229690	2267460	2324070
Portugal	1399535	1929102	1693860	1747634	1330482

Table 1: 15 highest tomato producers globally (Tonnes) FAOSTAT 2019

Country	2014		2015		2016		2017		2018	
	Tonnes	Ha	Tonnes	Ha	Tonnes	Ha	Tonnes	Ha	Tonnes	Ha
Egypt	8288043	214016	7737827	196853	7320714	184972	6729004	166206	6624733	161702
Kenya	443271	24531	402513	19027	410033	21921	507142	27636	599458	28263
Nigeria	4083500	541800	4229330	557500	3412650	829299	4100000	655906	3913993	608116
South Africa	513376	6856	558018	7353	629974	8405	672176	8935	537257	7116
Sudan (Former)	612000	42000	616700	44814	617400	46746	650099	50261	674378	50221

Table 2: Tomato production in Africa over a five-year period (2014 - 2018) FAOSTAT 2019

There exist a direct variation between the production output and hectares cultivated across the African regions however, there is a sharp contrast to this in West Africa (Nigeria) where there exist a shortfall in the production output as against the hectares cultivated (Table 2). Some of this shortfall could have been as a result of post-harvest losses however, the magnitude of shortfall during the pest infestation (2016) suggest more of biotic stress associated with the changes in atmospheric conditions experienced within the region. Consequently, the trend is maintained till 2018 hence making a case for the influence of biotic and abiotic stress on tomato production in the region. Farmer plays an important role by having impact on the quality of the produced tomato. The production is highly affected by the degree of the farmers' knowledge and on the support by regional and national institutions. Lack of knowledge and support are known to increase harvest losses [19]. Regional efforts to increase tomato production by smallholders in Africa has shown positive results, e.g. when novel leaf curl disease resistant tomatoes seeds were released in West Africa [20]. In addition, regional efforts in the horticultural production chain is known to benefit women, due to the fact that women represent 80% of the workforce in this production chain, and increasing yield and quality of the produce results in more decision power for women within their communities [21].

ADVANCES IN ADAPTATION TO BIOTIC AND ABIOTIC STRESS

Abiotic stress involves chilling, high temperature, osmotic shock, drought, salinity, water logging, wounding, exposure to ozone, toxic ions, excessive light and UV-B irradiation [22]. Unfortunately, abiotic stresses are complex in their nature but are controlled mostly by genetic and environmental factors that impede crop plant breeding strategies [23]. Abiotic stress can be identified by symptoms on leaves but most commonly observed symptoms are associated with certain diseases or nutrient deficiencies and requires keen observation of the stem or root to diagnose accurately. Abiotic stress in tomato plant may not be easily visible due to secondary colonizers such as pest and diseases albeit, it's advisable to consider multiple problems that might have reduced its productivity. An understanding of tomato plant physiology, genetic makeup of the variety, nutrient, weather and soil conditions helps to overcome combinatorial stress from biotic and abiotic conditions [24]. Reactive oxygen species (ROS) are a common signal that activate plant response to abiotic stress [25]. Plants are susceptible to ROS when their production exceeds the capacity of the plant to scavenge them. Tomato varieties that are naturally tolerant to drought and heat stress are identified to have ability to respond positively to oxidative damage and regulation of ROS that causes molecular damage and cell death. Production of ROS causes impairments in DNA, lipids and protein which eventually leads to cell death and progressive aging of the plant [26, 27].

A major determinant of biotic and abiotic stress in tomato crop production is low diversity among commercial tomato varieties and negative interactions at the phenotypical levels [10, 28]. Consequently, in order to survive biotic and abiotic stresses in their environment, plants have evolved complicated mechanisms to identify external signals thereby producing optimal responses through plant proteins and phytohormones [25]. Proteins are di-functional in the formation of new plant phenotypes by regulating physiological characteristics to adapt to changes in the environment and also in maintaining cellular homeostasis [29]. Phytohormones such as salicylic acid (SA), jasmonic acid (JA), ethylene (ET), and abscisic acid (ABA) primarily regulate plants' responses against biotic and abiotic stresses via synergic and antagonistic actions [30, 31]. Abscisic acid is a defense related phytohormone that promotes abiotic stress tolerance and suppresses signaling of the biotic stress-related hormone salicyclic acid. It signals in root-pathogen interactions where abiotic stress is encountered most directly [32]. ABA levels in tomato roots have been found to increase rapidly after salt stress exposure and during the onset of predisposition, and then decline to near pre-stress levels [32]. Indications for stress regulatory crosstalk can be found at the phenotypic level, and are evident as well at the gene expression level [28]. Recently, the transcriptome of Arabidopsis subjected to combinations of various abiotic and biotic stressors was analyzed [33 – 35]. In plants, polyamines not only play a role in abiotic and biotic stress, but also in many other physiological processes (organogenesis, embryogenesis, floral initiation and development, leaf senescence, fruit development and ripening) [36]. Recent studies have revealed that polyamine signaling is involved in direct interactions with different metabolic pathways and entangled hormonal cross-talks (e.g., abscisic acid involved in the regulation of abiotic stress responses) [36].

Breeding programmes have been used to achieve cultivars that are resilient to both biotic and abiotic stress in order to survive and reproduce genotypes that are tolerant to heat with locally adapted ascesions that are susceptible to these stresses can be bred to develop resistant varieties [37]. Recently, the introduction of transgenic technology has made transferrable traits of desirable genes that are resistant to abiotic and biotic stress possible and research on improved abiotic stress tolerance are ongoing. An offshoot of such research have developed transgenic tomato plants which over-expressed cytosolic ascorbate peroxidase (cAPX gene) with enhanced tolerance to heat (40OC), chilling and salt stress showed enhanced resistance compared to wild types. [29] found intricate molecular mechanisms to be involved in biotic stress and that Post-translational mechanisms (PTMs) are critical for rapid reprogramming of cells, defense signal transduction and attenuated response and are important means by which plants maintain cell homeostasis at all levels of the immune response. Proteins in plant cells are post-translationally modified by covalent addition of some chemical units or by changing the structures of the amino acids themselves. Also, tomato seedlings inoculated with Streptomyces thermocarboxydus strain BPSAC147 under greenhouse conditions had enhanced its resistance to abiotic stress and diseases. Tomato plants with a DNA containing Arabidopsis C repeat/dehydration-responsive element binding factor 1 (CBF1) cDNA and a nos terminator, driven by a cauliflower mosaic virus 35S promoter had been successfully transformed and had been more resistant to water deficit stress than wild type plants [38].

CONCLUSION

Global production output of tomato is on the increase with a view to meet the demand on consumption of the commodity. African regions are key contributors to the overall output albeit the attendant constraints associated with the growing zones are enormous and this has been further deepened in the wake of a changing climate. Tomato production per unit area in the African growing zones has been significantly low when compared with that obtainable from Asia, America and Europe. Genetic improvement of hybrid varieties should be crossbred with local landraces to confer superior resistant ability to stress as well as increased productivity per unit area. This should be accompanied with trainings on Global Good Agricultural Practices (Global G.A.P), inclusions on agricultural technological interventions and integrating soil management practices as well as building a structured value chain to cater for exigencies related to post-harvest losses.

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