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Tomato Leafminer (*Tuta absoluta* Meyrick 1917): A Threat to Tomato Production in Africa

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Authors' contributions

This work was carried out in collaboration between all authors. Author NZ designed the study and wrote the first draft of the manuscript. Author M. Chidege revised the 1st draft. Author CM revised the 2nd draft. Author M. Chacha revised the 3rd draft and managed literature search. Author ERM revised the 4th draft, managed the literature searches and designed the model. Author PAN revised the 5th draft and made conclusion. All authors read and approved the final manuscript.

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ABSTRACT

Tomato (*Solanum lycopersicum* L.) is an important vegetable crop for income, food and nutrition in Africa. Production of the crop is currently threatened by leaf miner [*Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae)]. Heavy infestation by *T. absoluta* has been reported to cause yield losses ranging from 80-100%. *Tuta absoluta* has high rate of reproduction and short life cycle making it very dominant in the infested tomato fields. Insecticide application for control of the pest is uneconomical for subsistence farming and beyond the earnings of majority of resource-poor farmers in Africa. Use of host resistance and or integrated pest management (IPM) strategies is slightly or not in use thus making the pest reign in the

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majority of African countries. This review discusses how *T. absoluta* threatens production and recommends some focal areas towards addressing this pest problem in the tomato industry in Africa.

Keywords: Tuta absoluta; tomato; Africa; pesticide resistance.

1. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is an important vegetable crop for income and nutrition of small-holder farmers in many parts of the world [1,2]. Tomato is cultivated throughout the year and in varied range of environments depending on abiotic factors [3,4]. Tomato fills the hunger gap as farmers usually sell tomato and spend the money obtained to buy cereal and leguminous crops for food during dry seasons. Despite the benefits of tomato, it is in danger of deterioration due to invasion by an exotic insect pest namely tomato leaf miner (*Tuta absoluta*. Meyrick) [5-7].The pest is wide spread in Europe, Asian and Africa [8]. *T. absoluta* is difficult to control due to inability of pesticides to reach the feeding larvae which is usually protected inside the tissue of the tomato plant host [9-12]. Economic losses due to *T. absoluta* infestation in tomato have been reported to be up to 100% in some countries in Africa particularly Sudan, Kenya and Ethiopia [12,13]. In efforts to control the pest, farmers use different options including increased spraying of chemical pesticides, to the levels that are uneconomical and harmful to non-targeted organisms [14,15]. Furthermore, increased chemical application by farmers impends health problems as chemicals persist in human bodies and maginifies pest resistance problems [11,16-18]. Thus, this review discusses the reproduction, epidemiology, strategies for infestation, current and prospective for management of the *T. absoluta* and its potential impact to tomato industry and food security in Africa.

2. IMPORTANT CHARACTERISTICS THAT MAKES *T. absoluta* DEVASTATIVE

2.1 Reproduction of *T. absoluta*

Tuta absoluta has high biotic potential including reproductive rate [19-21]. It is a multivoltine pest producing 250-300 eggs per female leading up to 12 generations per year [22,23]. Once an adult female emerges, it releases a sex pheromone that attracts males towards and this stage is associated with high oviposition rate and consequently high population within short period of time [24-26]. *T. absoluta* has overlapping generations and does not undergo diapauses in presence of food thus thriving over time [26-28]. *T. absoluta* can endure and adapt in harsh conditions such as extreme cold, dry conditions and hot environments [29]. *T. absoluta* has a wide range of alternative host plants including potato, egg plants, african egg plant, black night shade, amaranth and datura species that can harbor it to feed and reproduce in several seasons and at several ecological regions [30-33]. On scarcity of tomato, *T. absoluta* switch on other available host to retain its population and regain when tomato is plenty [34,35]. Hence availability of diversity hosts of *T. absoluta* in different seasons influences selection of the host that favors its reproduction and development [36-39].

2.2 Growth and Infestation Stages of *T. absoluta*

T. absoluta has four main growth stages namely egg, larvae, pupa and adult insect. Each of these growth stages is adaptive and has competitive advantage against chemical control options and environmental hazards. Larvae is the most difficult to control as it mine between the leaflets and tissues thus cannot easily be killed by contact sprays. Pupa pupates in the soil where chemicals and strong heat from the sun cannot easily destroy them and adults hide and lay eggs at undersides of the leaves to veil from predatory birds and unfavorable environmental conditions that can affect its development [40-42]. The infestation stages of *T. absoluta* on host tomato plant are described in Fig. 1. Infestation starts with chemical communication between host plants with the pest. The host plant which has ability to emit attractant chemical compounds and or essential oils compounds or volatile compound producing host (VCP-Host) attracts female *T. absoluta*, then the insect produces hormone that attracts males to mate. After mating, the pest may invade either a non VCP-Host or a VCP-Host. If it invades a non VCP-Host or if it invades the VCP-host and succeeds to lay eggs, but in the presence of a natural enemy (NE) colonization by *T. absoluta* may not

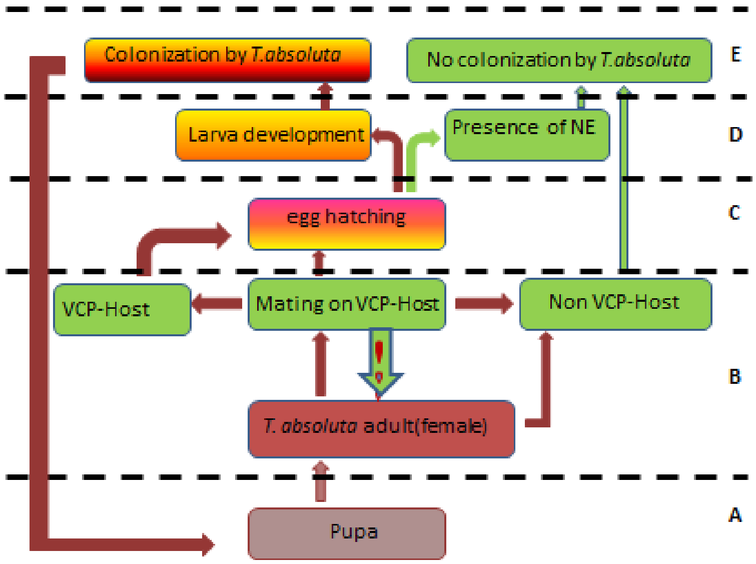

Fig. 1. A model describes infestation stages A to E by *T. absoluta* on host. Infestation starts at stage B. In this stage, a susceptible host or a volatile compound producing host (VCP-Host) emits attractant chemical compounds or essential oils compounds that attract female *T. absoluta*, then the insect produces a sex hormone that attracts males to mate. After mating, the pest may try to invade either a non VCP-Host or a VCP-Host. If it invades a non VCP-Host or if it invades the VCP-host and succeeds to lay eggs (stage C) in the presence of a natural enemy (NE) (stage D), no colonization by *T. absoluta* occurs on host plant (stage E). If it invades a VCP-Host and succeeds to lay eggs (stage C), the eggs will develop into larva (stage D) and the host plant will be totally colonized by *T. absoluta* (stage E). Then the larva exits from the infested plant and drops off the soil where it pupates (stage A) and then erupts into fully developed adult

occurs on host plant. If it invades a VCP-Host and succeeds to lay eggs, the eggs will develop into larva and the host plant will be totally colonized by *T. absoluta*. Then the larva completes its infestation stages by exiting from the infested plant and drops off the soil where it pupates and then erupts into fully developed adult.

2.3 Distribution

Distribution of *T. absoluta* is both triumphant due its ability to drift and spread quickly into a new area, and intercontinental since it is currently found in almost all continents [8]. Its dispersal is mainly attributed by wind [8]. This type of dispersal has advantage on the pest since, as it is moved by wind, its energy becomes available for reproduction [43-45,]. *T. absoluta* can also travel some kilometers by flying and can accidentally be dispersed by humans through local and international trading of unnoticed infested tomato [26,46-48]. South wind is reported to accelerate the spread of *T. absoluta* from South America to Africa [48]. For instance, *T. absoluta* was identified in South America, Peru then moved to Uruguay, Chile, Mexico, Argentina and further East [49-51], from South America east ward to Spain and reached Eurasian countries [52], including India , China and Japan [8]. Spread of *T. absoluta* in Africa has similar trend of southward where swiftly moved from Morocco, Senegal, Sudan, Somalia, Kenya Uganda, Malawi and other Southern Sub-Saharan Africa [53-56]. The pest is still spreading all over the world and is recently threatening tomato market in West Africa, particularly Nigeria [49].

2.4 Challenges with Chemical Pesticides

Conventional pesticides are commonly applied to control insect pests including *T. absoluta*. Some reports show the effect of chemical sprayers mainly harming untargeted organisms as well as environment and not the *T. absoluta* [57-59]. The nature of infestation especially by the *T. absoluta* larvae hiding inside protected tomato plant tissue and resistance to different chemicals limit control efforts [60-62]. Common chemicals that *T. absoluta* has been reported to develop resistance are Cartap [62], pyrethroids [63], organophosphates, spinosad, Emamectin benzoate and Abamectin [64], chloride channel activators, benzoylureas [65] and diamide [66]. Pest resistance has been reported to cause increased use of chemical pesticides applications against *T. absoluta* in many parts of the world [67]. In Spain, about 15 applications and in Brazil up to 30 applications have been reported [68,69]. Resistance of *T. absoluta* against spinosad chemical was reported to reach up to 180,000 folds within seven further generations in Brazil [64]. In countries such as Tunisia, more than 18 chemicals were introduced during 2009-2011 for the control of *T. absoluta* but none of them seemed efficient in solving the pest problem [70]. However, chemical pesticides are very expensive and are applied frequently to the extent that most small-holder farmers in Africa cannot afford to purchase regularly.

2.5 Scarcity of Host Resistant Tomato Varieties

Production of resistance varieties of tomato has gained more attention in some parts of the world such as South America where the pest originated [33,39,63,71-73]. However to-date, there seems limited or no clear information as whether there are successful tomato varieties which are resistant to *T. absoluta* [74-76]. Efforts to develop resistant varieties are going on in different parts of the world, but the pest seems to change rapidly and this may need more research efforts to identify the adaptation mechanisms and areas of weakness for effective control [12].

2.6 Yield Loss Due to *T. absoluta*

Insect pests including *T. absoluta* are reported to be accountable for destroying one fifth of the world's total crop production annually [77]. This is because most insects are herbivores and ecologically successful [78]. Insect pests have a high ability to manipulate environments and select suitable hosts [79,80]. Insect pests including *T. absoluta* are capable of evolving to biotypes that can adapt to new situations, such as overcoming the effect of toxic materials, some of which human beings use to control insect pests [81]. In Africa as in other parts of the world, insect associated losses has been reported to be as high as 80-100% in vegetables particularly tomato [58,62,82-86].

2.7 Potential Impact of *T. absoluta* on Tomato Production in Africa

Tomato industry is in danger of deterioration due to effect by *T. absoluta* if not controlled. Several authors [87-99] have consistently reported that, no effective control including use of chemicals is available for farmers. Parolin et al. [100] furthermore reported that without any practical solution to farmers, growers will lose all benefits that could be earned from tomato production. Though most farmers depend on tomato production for their livelihood, there is a risk that most farmers will switch to other crops due to massive losses due to *T. absoluta* that farmers experience in growing tomato [11]. Abandonment of tomato production can be due to yield loss and high costs of pest control above the threshold level that farmers would not afford [101,102]. This will have great impact to the economy of African countries and people who depend on tomatoes for income [103,104].

2.8 Management Prospective

Tomato growing farmers in Africa are currently stranded due to lack of effective control options as even under increased spay cycles, they experience massive losses due to *T. absoluta* [12,105]. This however has opened a new window for research and development of new and alternative control measures. The most recommended and promising approaches include application of biological control options such as parasitoids and nematodes [106-109], entomopathogenic fungi and bacteria [97], and pheromone traps for monitoring population as well as detection of their presence [107,110,111]. Screening and breeding for resistant of host tomato plants is considered effective in overcoming the pest and efforts are going on [112-115]. As these may be long time strategies which may not be readily available for Africa, there is need for multidisciplinary efforts involving research scientists, agricultural extensions, economists, policy makers, politicians and farmers to build a united priority in developing appropriate management options to rescue tomato industry which is currently in danger of deterioration in Africa. Moreover, molecular characterization of *T. absoluta* is of great importance for confirmation of the pest as it moved in different regions with various conditions that might affect the genetic aspect of the pest.

3. CONCLUSION AND RECOMMENDATIONS FOR FUTURE RESEARCH

T. absoluta is an impending threat to tomato in Africa. There is currently no single control option that has proven to be effective against *T. absoluta*. Use of host resistance and or integrated pest management (IPM) strategies is slightly or not in use thus making the pest reign in the majority of African countries. Thus, there is need for multidisciplinary efforts involving research scientists to find out genetic mechanisms and strategies that will halt further colonization of *T. absoluta* in Africa; agricultural extensions to communicate practical agricultural solutions to farmers; policy makers to establish appropriate policies; and farmers to apply developed/recommended solutions for sustainable tomato production in Africa.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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