Sudan University of Science and Technology

College of Graduate Studies

Bio-rationale Management of *Tuta absoluta* Meyrick (Gelechiidae: Lepidoptera) using some Sudanese Tomato Accessions and Extracts of some Botanicals

الإدارة الحيوية الرشيدة لحافرة أوراق الطماطم *Tuta absoluta*

بإستخدام سلالات مقاومة من الطماطم السودانية وبعض المستخلصات النباتية

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By:

Elharith Hamed Bakheit Mohammed

B. Sc. Agric. (Honors) (2000) Omdurman Islamic University

M.Sc. Plant protection. (2005) Sudan University of Scienceand Technology

Supervisor: Prof .Dr. Awad Khalafallah Taha

College of Agricultural Studies – Shambat

Department of Plant Protection

Co Supervisor: Dr. Mohammed elnazeir Elfadil Mahmoud

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بسم الله الرحمن الرحيم

قَالَ تَعَالَىٰ:

﴿ أَوَلَمۡ يَرَوۡاْ أَنَّا نَسُوقُ ٱلۡمَآءَ إِلَى ٱلۡأَرۡضِ ٱلۡجُرُزِ فَنُخۡرِجُ بِهِۦ زَرۡعٗا

تَأۡكُلُ مِنۡهُ أَنۡعَٰمُهُمۡ وَأَنفُسُهُمۡۚ أَفَلَا يُبۡصِرُونَ ﴾

صدق الله العظيم

سورة السجدة الأية (27)

Dedication

To my father and mother whom I love too much

To my wife and daughters ,Malaz. Hala and Aseel

To my brothers and sisters I wish to them a

beautiful life

To all my family

To all my teachers and friends with

To the spirit of Dr. Abdallah Elhassan

Love

&

respect

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Abstract

The tomato fruit borer, *Tuta absoluta* (Meyrick) (lipodopetra: Gelechiidae) ,was the most serious incest pest of tomato during the last decade threatening its production all around the world. The pest is highly aggressive was capabilities to invade new territories, affecting tomato and many other host plants. Different management procedure were adopted in many countries, Including the use of insecticides to control *T.absoluta.*Reliance on chemicals to control insect pest is hazardous to human, animal, beneficial insects and environment; also it generates insect resistance and leads to resurge of non-harmful ones. This study was initiated to mitigate the damage caused by *T absoluta*, look for alternative bio-rationale eco-friendly management tactics, benefited from the nature through assessment of the possibility of tolerance/ resistance of some tomato local accessions and assessing the effect of extracts of some botanicals on larval mortality. Twelve Sudanese tomato accessions provided by Plant Genetic Resource Centre of ARC (Wad Medani, Sudan) were evaluated for their resistance to *T. absoluta* in field experiments carried for three winter seasons,2017/18,2018/19 and 2019/20, in the farm of Kassala an Gash Research Station, in Takroof area, Kassala, Sudan. The experiments were arranged in a randomized complete block design (RCBD) with three replicates. Parameters include, number of active mnes, percentage of infested plants, percentage of infested fruits, yield, fruit diameters, days to 50% flowering fruit. Total soluble solid and number of trichomes of leaves were used as indicators for the susceptibility, tolerance or resistance of the tomato accessions. Chemical constituents; Lycopene, Tannin, Ascorbic acid and carotene of different test accessions and hybrids were determined using Elico SL-150 UV-Vis spectrometer device ,applying different analysis standard protocol.The effects of oil extracts of Neem, *Azadirchta indica Ajuss*, aqueous extracts of Datura, *Daura stramonium* and Periwenkle, *Venca rosea*L, were evaluated against the infestation of T. absolua and yield of tomato in randomized complete block design field trials.The results of evaluation of accessions and hybrids of tomatofor resistance to T. absoluta showed high significant difference (pr>f<0001) for the percentage of infested plants/plot, mean number of active mines/plot percentage of infestedfruits/plots, Total Soluble Solid (TSS), fruit diameter (cm^2) and yield of tomato (Ton/Ha) for the first , second and third seasons, combined results of the three season and the interaction between seasons and accessions and hybrids. Also High significant difference was revealed between accessions and hybrids on the number of trichomes/$cm^2$of leaves and content of Lycopene, Tannin, Carotene and Ascorbic acid. Accessions HSD6071 and HSD14358 recorded the least percentage of infested leaves/plot, least number of active mines/plot and least percentage of infested fruits/plot .The same three accessions obtained the highest TSS, highest fruit diameters (cm) and highest yield (Ton/Ha) and highest number of trichomes/cm^2 of leaves. For the chemical constituents of accessions HSD14358 obtained the highest content of Tannin followed by HSD11429 and HSD6069. Lycopene content was found in high percentage in HSD4420, HSD4419 and HSD6639 while HSD6069, an HSD6639contained the highest percentage of Carotene.On other hand, the content of Ascorbic acid was found greatest in HSD4419, HSD10665.TSS was found correlated highly negative with the percentage of infested leaves/plot (.0.82977,<.0001), number of mines/plot (-0.84764,<.0001) and percentage of infested fruits/pot (-0.81465, <.0001) and correlated highly positive with yield (0.64773, <.0001) Tannin correlated moderately negative(0.5409, <.0001) with the percentage of infested plant/plot and correlated weekly negative with the number of the active mines/plot and correlative (-0.5409, <,001) with the number active mine /plot aswell as percentage of infesed plant /plot(-0.5409, <,001) and mean number of mines (0.8342 <.0001) . Result of evaluation of the effect of some botanicals to control *T. absoluta* revealed high significant difference between treatment percentage of infested plants number of active mines and yield while significant differencewas observed between treatment in the percentage of the infested fruits.Water extracts of Datura and Neem seed oil were better in reduction of percentage infested plants and number of active mines /polants. All extracts of 3 elites tested plants were better reducing fruit damage percentage and boost tomato yield better than non treated treatment. The obtained results in this study showed the three Sudanese local accessions HSD 6071,HSD11429 and HSD14358 are potent to tolerant infestation of *T. absoluta* and increase yield of tomato due to their hairiness inclusion of high oercentage of tannin and high count of total soluble solid The three elite accessions can be introduce as sourse of resistance to *T. absoluta* . . The excellent control of *T. absoluta* and increment of tomato yield using neem seeds oil and water extracts of Datura and wenca encourage farmes to reduce synthetic insecticides and reduce health hazards and pollution.”Seeds Propagations Program” should be followed to quantify the amount of seeds of the three elites to obtain the gene or genes responsible of resistance and use them for crossing and breeding program

ملخص الدراسة

تعتبر ثاقبة ثمار الطماطم *Tutaabsoluta* (Meyrick) (Lepidoptera:Gelechiidae)من أخطر الآفات التي تصيب محصول الطماطم خلال العقد الماضي والتي تهدد انتاجها في جميع انحاء العالم . تعتبر الافة شديدة الضراوة ولديها القدرة علي غزو مناطق جديدة توثر علي انتاج الطماطم والعديد من النباتات العائلة الاخري . تم تبني اجراءات ادارة مختلفة للافة ف العديد من البلدان بما في ذلك استخدام المبيدات الحشرية للمكافحة. الاعتماد علي المبيدات الكيمائية لمكافحة الافات الحشرية امر خطير علي الانسان والحيوان واليئة كما انه يولد مقاوة الحشرات وظهور حشرات ضارة . اجريت هذه الدراسة للتخفيف من الضرر الناجم عن حفار الطماطم علي الانتاج . صممت هذه الدراسة للبحث عن تكتيكات ادارة للافة باستحدام طرق صديقة للبية بديله للكيماويات بالاستفادة من الطبيعة من خالال اختبار وتقييم امكانية تحمل او مقاومة بعض المدخلات المحلية من الطماطم للاصابة بحفار ثمار الطماطم وكذلك تقييم تاثير مستخلصات بعض النباتات علي الافة نفسها ثم تقييم اثني عشر مدخل من مدااخيل الطماطم السودانية التي تم توفيرها من مركز الموارد الوراثية النباتية التابع لهيئة البحوث الزراعية السودانية (ود مدني) لاختبارمقاومتها لحفار ثمار الطماطم بمزرعة محطة بحوث كسلا والقاش في منطقة تكروف بمدينة كسلا ، السودان . تم اجراء التجارب بتصميم القطاعات الكاملة العشوائية (RCBD)بثلاث مكررات لمدة ثلاثة مواسم شتوية (2017/18,2018/19,2019/20) كانت الموشرات لقابلية التحمل او المقامة لمدخلا الطماطم تشمل : عدد الانفاق النشطة ، النسبة المئوية للنباتات المصابة، النسبة المئوية للثمار المصابة ، قطر الثمرة ، عدد الايام لازهار 50% من النياتات ، اجمالي السكر القابل للذوبان ، عدد الشعيرات من سطح ورقة النبات وانتاجية المحصول . كذلك شملت المشرات تحديد المكونات الكميائية للمداخيل بالاخص اللايكوبين والتانين وحمض الاسكوربيك والكاروتين لمداخيل الطماطم باستخدام بروتوكولات تحليل قياسية مختلفة . ايظاً تم دراسة تاثير مستخلص زيت النيم والمستخلصات المائية لنبات السكران ، ونبات الوينكا علي موشرات الاصابة في الطاطم بحافرة ثمار الطامطام وكذلك تاثريها علي الانتجية . اظهرت نتائج تقييم مدخلات وهجن الطمامطم لمقاومة حفار ثمار الطماطم فروقات معنوية عالية للموسم الثلاثة والتحليل التجميعي للمواسم الثلاثة وكذلك سجلت الفروقات المعنوية العالية بين المواسم للتفاعل بين المواسم والمدخلات والهجن لكل من نسبة الاوراق المصابة ، عدد الانفاق النشطة ، نسبة الثمار المصابة ، الانتاجية ، قطر الثمرة ، اجمالي المواد الصلبة القابلة للذوبان وعدد الشعيرات ، كذلك اوجدت الدراسة فروقات معنوية عالية بين المداخيل والهجن في عدد الشعيرات للورقة ومحتوي النبات من اللايكوبين والتانين والكاروتين وحمض الاسكوربيك . المدخلات HSD14358,HSD6071و HSD11429 سجلت اقل نسبة من الاوراق المصابة ، واقل عدد

من الانفاق النشطة واقل نسبة من الثمار ال مصابة بينما حصلت نفس المدخلات علي اعلي نسبة من المواد الصلبة الذائبة واعلي اقطار للثمار واعلي انتاجية للمحصول واعلي عدد من الشعيرات من الاوراق . بالنسة للمكونات الكميائية للموخلات حصل HSD14358 علي اعلي محتوي من التانيتن يليه HSD11429و HSD6069 تم تسجيل نسبة عالية من اللايكوبين للمداخيل HSD4420 و HSD4419 و HSD6639 بينما احتوت HSD6639 و HSD24420 و HSD6069 علي اعلي نسبة كاروتين . من ناحية اخري وجد ان محتوي حمض الاسكوربيك اكبر في HSD10665 و HSD10689 و HSD 4419.وجد ان المواد الصلبة الذائبة ترتبط ارتباط عالي السلبية مع النسبة المئوية للنبتات المصابة (‎-0.82977,<0001‎) ، عدد الانفاق النشطة (‎-0.84764,<0001‎) والنسبة المئوية للثمار المصابة (‎-0.82977,<0001‎) زات ارتباط عالي الايجابية مع انتاجية (‎-0.64773,<0001‎) ، ايظاً اظهرت الدراسة ان التانين يرتبط ارتباطاً سلبيا متوسط (‎-0.5409,<0001‎) ، مع النسبة المئوية للنبتات المصابة وارتباط سلبي ضعيف مع عدد الانفاق النشطة وكذلك النسبة المئوية للثمار المصابة . لوحظ ارتباط سلبي قوي جدا بين عدد الشعيار من الاوراق والنسية المئوية للنبتات المصابة (‎-0.8749,<0001‎) ، وعدد الانفاق النشطة (‎-0.8242,<0001‎) ، نتائج تقييم تاثير مستخلصات بعض النباتات عللي حافرة ثمار الطماطم بالمقارنة مع المبيد المعياري والشاهد اظهرت فروقات معنوية عالية جداً في تقيل النسبة المئوية للنيتات المصابة وعدد الانفاق النشطة وكانت جميع المستخلصات النباتية المختبرة افضل من المبيد والشاهد في تقليل نسبة تلف الثمار وزيادة ا لمحصول . اظهرت النتائج المتحصل عليها في هذه الدراسة ان مداخيل الطماطم السودانية المحلية HSD6071 و HSD11429 و HSD14358 قادرة علي تحمل الاصابة بثاقبة ثمار الطماطم وزيادة انتاجية محصول الطماطم الذي يعزي احتواء الاصناف ع دد اكبر من الشعيرات ، نسبة اعلي من المواد الصلبة الذائبة وكذلك وجود نسبة عالية من التانين . يمكن تقديم المداخيل الثلاثة لبرنامج تربية النبات كما ان المكافحة الجيدة لحافرة اوراق الطماطم والزيادة في محصول الطماطم الناتجة من استخدام زيت بذور النيم والمستخلص المائي لنباتي السكران والوينكا يمكن ان يشجع المزراعين علي التقليل من استخدام المبيدات الحشرة الاصطناعية وبالتالي تقليل المخاطر الصحية والتلوث . يجب اتباع" برنامج اكثار البذور" وتحديد كمية البذور لكل من هذه المداخيل الثالثة المنتخبة وتوزيعها علي المزارعين ، كما هناك حاجة ملحة لاجراء دراسات مستقبلة لتحديد الجينات المسئولة عن المقاومة واستخدامها لربنامج تربية النبات.

CHAPTER ONE

INTRODUCTION

Tomato *(Lycopersicon esculentum mill.)* is one of the most leading vegetable crops worldwide with acreage under production estimated at 5.030.545 hectares and production of a total output close to 180.765.302 metric tons in 2019 (FAO, 2019).Tomatoes are nutritious and low in calories. One medium –size tomato provides 57% of the Recommended Daily Allotment (RDA) of vitamin c, 25% RDA vitamin A, and 8% RDA iron, yet it has only 35 calories. Besides being eaten fresh, the versatile tomato can be sald, stewed, fried and juiced. It can be used in soups, salads and sauces (Anonymous, 2015). Tomato plant is very versatile and the crop can be divided into two categories; fresh market tomatoes and processing tomatoes.

In Sudan, the main production areas are concentrated in the northern part of Gezira scheme, southern part of Khartoum state (El Assi, 2001). In the 1950, production of the crop was limited to winter season. Early produce reaches the markets by mid-October supplied mainly from small holdings grown along the river banks as flood crop. Nowadays tomato is produced all around the country in winter and summer season (Mohammed *etal.*, 2012).

Tomato crop has been reported to be attacked by different pests and diseases that have the potential to drastically reduce its yield such as yellow leaf curl virus disease which is transmitted by whitefly, leaf miners *Liriomyza spp*, American Boll Worm (ABW) and Tomato fruit borer *Tuta absoluta* (Kumar and Omkar, 2018. EPPO,2005). The tomato leaf miner, *T. absoluta* is an alien invasive pest of solanaceous crops especially tomato. The feeding of larvae cause significant damage on leaves, stems and fruits leading to significant yield losses of up to 100% if the pest is not controlled (Desneux, 2010). *T. absoluta* is native to Central America but has spread to south America and more recently to North Africa and the Middle East. It was first detected in Europe (Spain) in 2006 and since that time it become a major problem to tomato growers in many European countries *T. absoluta* attacks all aerial parts of tomato plant and can result in tomato yield losses up to 100% in greenhouse and open-field (Desneux et al., 2010).Besides tomato, the host range of *T. absoluta* includes plants in: Solanaceae family (*Capsicum annuumL., Solanum melongena L., S. Nicotiana tuberosum L.,tabacum L.,Datura stramonium L.*), Fabaceae family (*Phaseolus vulgaris L., Medicago sativa L.*), Amaranthaceae family (*Chenopodium rubrum L. Spinacia oleracea L.*), and others (Ferracini *et al*., 2012; Mansour *et al*., 2018 Mohamed *et al*., 2012).In Sudan, *T. absoluta* was officially recorded as a serious pest of tomato in 2011 (Mohamed and Khalid, 2011). This pest is no doubt one of the main reasons for the decline of tomato yield in Sudan(Mahmoud *et al.*, 2020). Its outbreak was observed in many states in the country with a damage up to 80%(Mohamed and Mahmoud, 2013). In Sudan and temperate region, *T. absoluta* has about 12 generations per year and female can lay 250 to 300 eggs although its high heat tolerance and overwintering capacities enable it to quickly multiply over time, which complicates its management (Garzia *et al*, 2012). During its lifespan. *T. absoluta* is a major threat to tomato production in Sudan. Develop sustainable tactics for its controls highly required to increase productivity, refreshing the economy, alleviating poverty, and improving nutrition (Clay and Turatsinze, 2014). Application of insecticides is the main method used to control *T. absoluta* in Sub-Saharan Africa, including Sudan, due to lack of other procedures (Mansour *et al*., 2018). Due to development of resistance for the repetition use of insecticides and their adverse effect on natural enemies, short life span of the *T. absoluta* and entophytic feeding of its larvae, the use of insecticides is not recommended as a sole solution for this pest. (Garzia *et al.,* 2012; Roditaski*et al.,* 2015; Biondi *et al.,* 2018; Mansour *et al.,* 2018). Developing alternative tactics for management of *T. absoluta* is considered as a worldwide priority (Biondi *et al*., 2018; Mansour *et al.,* 2018). Plant resistance; screening of local varieties or accessions to identify morphological character or gene responsible of resistance, is one of the most important defense mechanism that play a vital role in management of the specific pest. Also application of cultural practices, using of pheromone for mass trapping of males, use of bio-rationale control agents such as plant extracts entomopathogenic fungi (EPFs), or nematodes (EPNs will reduce risks of use of insecticides and provide sustainable management of *T. absoluta.* (Jallow *et al.,* 2019; Isman, 2020; Nishi *et al.,* 2020).

The increase of world population in developing countries including Sudan is a challenge that requires extensive research work to magnify food production. Tomato is the important vegetable crop for various nations in the world and used as fresh salad, sauce, paste and as food additives. Among the major constraints limiting production are insect pests, particularly *T. absoluta*. Strategies to reduce the production losses due to *T. absoluta* is mainly relies on heavily use of chemical pesticides without any regards to the complexities that caused to ecosystem, particularly pollinators, natural enemies, animal and human. For farmers it is no economically or logistically feasible to use chemical pesticides which is very expensive. Therefore, they must depend on more fundamental approaches to pest management, such as the use of resistant cultivars.

The main objectives of this study were:

1-To Screen some tomato genotypes for resistance to *T. absoluta*..

2-To determine tolerance or resistance mechanisms through measurement of the length of the trichomes and chemical constituents of accession and hybrids.

3-To screen some plant extracts for the management of *T.absoluta* and determine its effect on yield.

CHAPTER TWO

LITERATURE REVIEW

2.1 Tomato *Lycopersicon esculentum* production in Sudan

2.1.1 Tomato production areas and yield in Sudan

The exact date of introduction of tomato into Sudan has not been recorded. However, it is possible that the tomato was first introduced by Egyptians in 1821(Mustafa,1999). Tomato ranking second to onion in terms of cultivated vegetable crop areas. The main production areas of tomato are Gezira Scheme (more than 16000 feddan = ha), the river banks in Gezira State (About 1847 feddan = ha). especially in Botana province, South Blue Nile, Kassala and Khartoum States (Mohamed, 1995). in central Sudan, tomato is grown and extensively produced in agricultural areas around cities (El Assi, 2001). In the 1950th, production of the crop was limited to winter season and by the mid- 1970s, tomato was made available to consumers all the year round. The selling price during off season crop however, remained very high. Tomato production and harvested area in Sudan reached 53,022 h in 2019 and the production reached 676,623 tons in the same year (FAO, 2019).Tomato production is affected by many insect pests and diseases, the most important of them are: yellow leaf curl, *Alternaria* spp, white fly *Bemesia tabaci*, African boll worm *Helcoverpa armigera*, leaf miner *Liriomyza spp* and recently the tomato fruit borer *T. absoluta*. These pests cause serious yield and quality losses by feeding on leaves and fruits (Shashank.,*et al*,2016).

2.2 T. absoluta

2.2.1 Classification

Phylum: Arthropoda

Class: Insecta

Order: Lepidotera

Family: Gelechiidae

Species: *Tuta absoluta* (Meyrick, 1917).

Common names: tomato fruit borer, South American tomato moth, tomato leaf miner, South American tomato pinworm (English (Agropedia,2011).

Common usename: Tomato leaf miner

2.2.2 Taxonomic history and synonyms

The generic assignment of *T. absoluta* has been questioned. Povonly (1994) splited the species among many genera, several of which he described himself and many of which he later synonymized. Other Gelechiid taxonomists have questioned the validity of many of these genera. Three genera that included North American species, including *Tuta*, were recently synonym zed in the checklist of North American Gelechiids by Lee *etal*, (2009). However, the publication did not list *absoluta* as a new combination because *absoluta* does not occur in North America (Brown, 2010). Meyrick described *Phthorima absoluta* in 1917 from a single adult male collected in Huancayo, (Meyrick, 1917).The species was reported in the coast of Chile and transferred to Gnorimoschema by Clarke (1965) as a new combination.

Clark also mentioned specimens reared from potato and tomato from Chile Peru and Venezuela. *T. absoluta* is a devastating pest of tomato. It is originating from South America.

2.2.3 Geographical distribution

T. absoluta is originated from South America. It is a serious pest in South America since the 1980's and was still in Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela (EPPO, 2005). Since its appearance in Spain in 2006, this pest is spreading rapidly across Southern Europe and North Africa to the whole of the Mediterranean countries. Until today *T. absoluta* has been reported in Italy, France, Malta, United Kingdom, Greece, Switzerland, Portugal, Morocco, Algeria, Tunisia, Libya and Albania. EPPO (2008a), EPPo (2008b), EPPO (2008c), EPPO (2009a), EPPO (2009b), EPPO (2009c), EPPO (2009d) and Fera (2009).

In Sudan, this pest was first detected in Khartoum State and rapidly spread to all tomato growing areas in the country (Mohammed *et al*., 2012). In 2017 the pest was reported from various countries of Africa including South Africa ((Visser *etal.*,2017).

2.2.4 Host plants of *T. absoluta*

Most of plant species belonging to the family solanacae are the preferred hosts for *T. absoluta* but Tomato is the main host followed by potato (CIP, 1996; Galarza, 1984; Notz, 1992), *Lycopersicon hirsutum*, *Solanum lyratum* and various wild solanaceous species such as *Solanum nigrum*, *Solanum elaeagnifolium*, *Solanum puberulum*, *Datura stramonium*, *Datura ferox* and *Nicotiana glauca* (Mohamed *etal*., 2012).

2.2.5 Biology and Ecology of *T. absoluta*

T. absoluta has a high reproductive potential with a single female. Females use pheromones to attract males for mating once a day for several days and laying approximately 260 eggs in its life time (EPPO, 2005) (Uchoa-Fernandes *et al*., 2005). Eggs were laid individually falling on the night on the upper third of the plant (Coleacp PIP 2013). *T. absoluta* has been observed to have five generations per year in Argentina (Korycinska and Moran, 2009) and 12 generation per year in Sudan (Elhag *etal*., 2015).

For feeding, larvae of *T. absoluta* prefer leaves, stems, buds, or the calyx over tomato fruit (FERA, 2009). Diapause in larvae does not occur unless food is unavailable (EPPO, 2005). Development stops between 6 and 9^{o} C [42.8 and 48.2^{o} F] (Barrientos *etal*.,1998, Betancourt, 1996). *T. absoluta* goes through four larval instars (Vargas, 1970) and pupation places are dependent on environmental conditions and can occur in the soil, on leaf surfaces, or in mines (EPPO, 2005). Larvae may be covered by a cocoon when pupating on or in host plants (van Deventer, 2009).Depending on environmental conditions. The lifecycle may take 29-38 days (EPPO, 2005). In laboratory experiments, the development of *T. absoluta* averaged 76.3 days at 14^{o} C, 39.8 days at 19.7^{o} C and 23.8 days at 27.1^{o} C (Barrientos*etal*.,1998). In a green house with a year-round tomato crop, *T. absoluta* could have approximately 9 generations (Potting *et al*., 2009). Adults are nocturnal and may be found hiding between leaves during the day (FERA, 2009). The mothspecies may survive colder climates in greenhouses, possibly spreading to field crops during warmer months (Potting *et al*., 2009).

Plate No.1: Developmental stages of *Tuta absoluta*
Source: Harizanova *et al*. (2009)

2.2.6 Diapause:

The larval stage does not enter diapause as long a nutrition is available, never wintering was observed in South Europe and North Africa (EPPO., 2005). a pupate in the soil, although pupation may also occur on the leaves.

2.2.7 Major hosts:

Tomato leaf miner feeds mainly on solanaceous hosts; however, other hosts may be attacked occasionally. More of its known hosts are include: *Solanum lycopersicum* (tomato), *Solanum tuberosam* (potato), *Solanum melongena* (Eggplant), *Capsicum annuum* (pepper), *Nicotiana tabacum* (Tobacco), *Solanum nigrum*, *Datura stramonium*, *Solanu meleagnifolium*, *Physalis peruviana*. *Solanum bonariease*, *Solanum sisymbriifolium*. *Datura ferox*, *lyceum sp*. and *Malvasp* (Vargas, 1970; Nappo- Pas, 2008; Korycinska and Moran, 2009, Potting *et al*., 2009, Mohamed *etal*., 2012).

2.2.8 Role of *T. absoluta* on transmitted plant pathogens:

This pest is not currently known to vector any pathogens or other associated organisms. However, damage by *T. absoluta* may lead to invasion by secondary pests.

2.2.9 Damage:

The larvae of *T. absoluta* mine the leaves producing large galleries and burrow into the fruit, causing a substantial loss of tomato in protected and open field cultivations (Chherti, 2018). The larvae feed on mesophyll tissue and make irregular mine on leaf surface. Damage can reach up to 100%. This pest occurs throughout the entire growing cycle of tomatoes.

*T.absoluta*has a very high reproduction capability. There are up to 10-12 generation per year in favorable conditions. The larvae are very unlikely to enter diapauses as long as food source is available. *T. absoluta* can overwinter as eggs, pupae and adults. Adult female could lay hundreds of eggs during her life time. Tomato plants can be attacked from seedlings to mature plants. In tomato, infestation is found on apical buds, leaves, and stems, flowers and fruits, on which the black frass is visible. *T. absoluta* reduced yield and fruit quality of tomato grown in greenhouse and open field. Severely attacked tomato fruits lose their commercial value and 50-100% losses have been reported on tomato (EPPO, 2005).

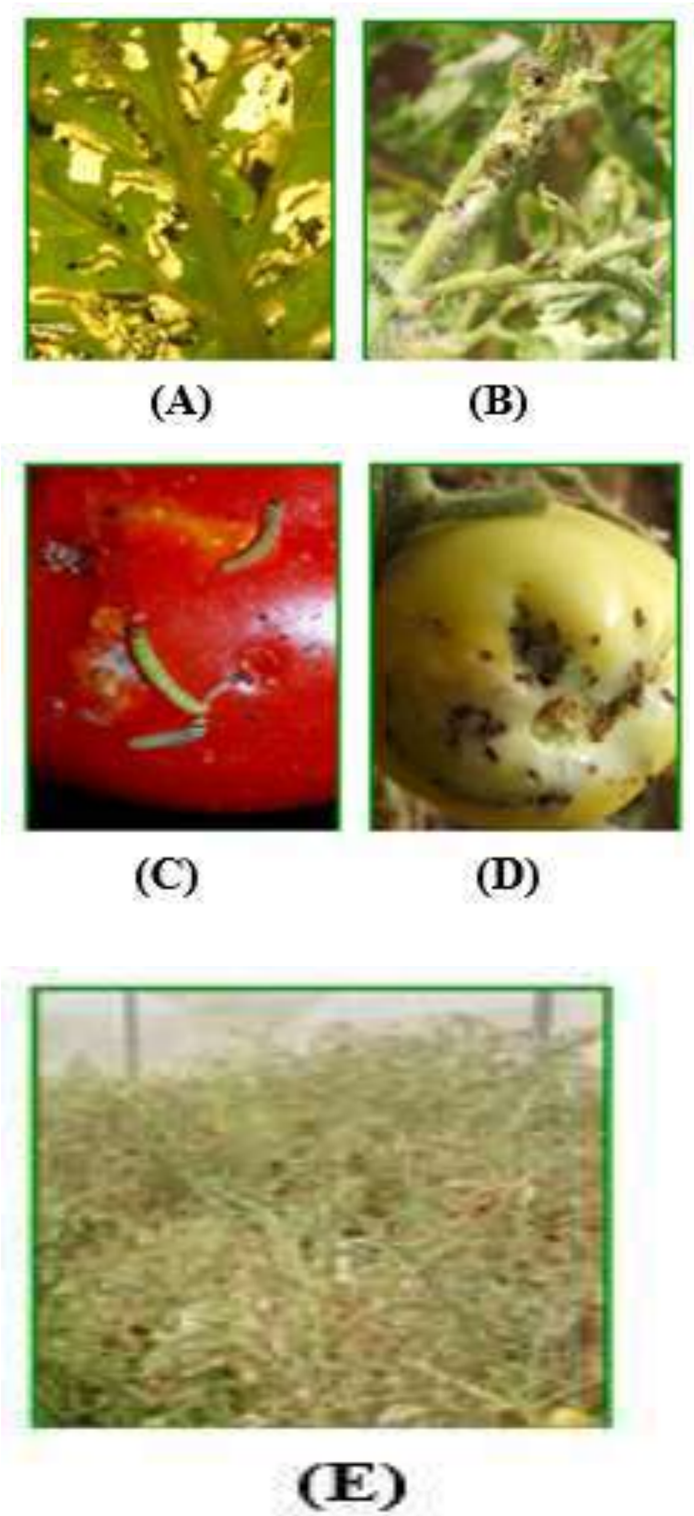

Plate No.2: Damage by *Tuta absoluta* on tomato crop. Larvae in leaf galleries (A), on caused shoots (B) and fruit (C); damaged tomato fruit (D) and crop (E).
Source: IRAC (2011).

2.2.10 Monitoring of *T. absoluta*

The use of pheromone traps is a reliable method to detect the presence of *T. absoluta*. Pheromone trap data give early warning of the infestation and also will alert the user to low level of populations before they become serious (Anonymous, 2015). Russell IPM manufactures and supplies pheromone lures, traps and complete monitoring systems for *T. absoluta*. TUA pheromone gives early warning of infestation and also exhibits the density of the insect accurately in low population to medium level of infestation. Male attractants baited in traps was used to monitor the population dynamics and seasonal abundance of *T. absoluta* in tomato plantation on various studies in Sudan. (Elhag*et al*., 2015, Mahmoud *etal*., 2020) .

2.2.11 Management of *T. absoluta*

2.2.11.1 Cultural Control

There are a number of cultural control method that aid the eradication and prevent the further buildup of a potential population of this pest These practices include crop rotation, selective removal and destruction of infested plant parts as well as removal of the wild host (Anonymous, 2015).

2.2.11.2 Host plants resistance

Host plant resistance was explored by developing tomato accession with high zingiberene and/or acylSoluble content resulting on low ovipostion rates and larval feeding of *T. absoluta* (Azevedo *et al*., 2003; Maluf *et al*., 2010).The contribution of tomato pest-resistance varieties among these practices used for control *T. absoluta* is meager. This may be due to the character of the tomato plant, which has been claimed to have a narrow genetic base (Zekeya *et al.*,2017). However, the development of pest-resistance tomato varieties has been intensively pursued since the early 1990s, particully in Brazil. Host range is constrained by the behavioral and physiological traits of the insect (Suckling *et al*., 2014). Although causing large injuries on tomatoes, *T. absoluta* is also considered to develop on other cultivated and non-cultivated Solanaceae,such as potato (*Solanumtuberosum*, Linnaeus), tobacco (*Nicotiana tabacum* Linnaeus), and black nightshade (*Solanum nigrum* Linnaeus) (Desneux *et al*., 2010, 2011; Mohamed *et al*., 2015).Khederi*etal*., (2014) reported that Trichome type and density of tomato genotypes related negatively to the population density of *T. absoluta.*

2.2.11.3 Chemical control

Chemical control has been the main control procedure applied against *T. absoluta* since it was reported in South America. In Brazil, Sudan and other countries tomato farms received up to 36 insecticide sprays to reduce population of *T. absoluta* within one cropping season. As results of reliance on frequent spray of insecticides to control *T. absoluta* resistance was noticed for several groups of insecticides. Resistance to Abamectin and Deltamethrin had been reported in Argentina (Lietti et al., 2005). Siqueira *et al*. (2000) reported reduction of susceptibility of *T. absoluta* to Abamectin, Cartap, Methamidophos, and Permethrin, which could indicate resistance development. However, there were active ingredients found to be effective against *T. absoluta* larval infestation in Spanish outbreaks: Imidacloprid, Indoxacarb and Spinosad. It is also reported that Deltamethrin has provided effective knock down of adult in Spain (FERA,2009).

2.2.11.4 Application of pheromones in management of *T. absoluta*

2.2.11.4.1 Mass trapping

Mass trapping is a technique that involves placing many number of traps in the crop field in various strategic positions to remove sufficiently high proportion of male insects from the pest population. It is widely used in conjunction with other control measures. Mass trapping is a potential option for open field production. However, for practical reasons, application in protected agriculture has a higher chance of success (Anonymous, 2015). Qlure- TUA with its high capture rate is ideal for mass trapping of *T. absoluta* particularly for protected tomato cultivation. It helps to reduce population in greenhouses particularly when insect exclusion nets and tight doors were used. TUA-Optima 0.8 mg; Tuta Long life and TUA-100N) proved their effectiveness on mass trapping males of *T. absoluta* using water traps in Sudan (Mahmoud *etal*., 2020).

2.2.11.4.2 Lure and kill:

Lure and kill is a very promising approach to control the male adults of *T. absoluta* with minimum amount of insecticide application. This will reduce the mating incidence and therefore reduce the number of viable eggs. Based on sustained release matrix, lure and kill product can release the pheromone over a long period normally over 6-8 weeks while sustaining the activity of the contact insecticide throughout the same period. Lure and kill technique is normally a single application, provides safe yet constant control over a long period. Pheromones of other pests may be incorporated to reduce the need to other insecticide applications. It is a targeted application in specific locations providing a safe environment for beneficial insect to develop and to participate in the overall control strategy (Anonymous, 2015). (Mahmoud *et al*., 2020).

2.2.11.5 Biological control

Trichogramma pretiosum, Trichogramma achaeae, *Mascrolophus pygmcus* and *Nesidiocoris tenuis* have been reported as bio-agents that control *T. absoluta* naturally. The egg parasitoid, *T. achaeae* has been identified as candidate for biological control of the south American Tomato pinworm, *T. absoluta*. On greenhoue conditions, a high efficacy (91.7%) of damage reduction was obtained when releasing 30 adults/plant (=75 adults /m2) every 3-4 days on August and September of 2008 in the south Spain (Cabello*et al*., 2009). The damsel bug *N. pseudoferus* was applied in Spanish green house. Two semi field bioassay on tomato plants, under controlled conditions, had shown an important reduction in the number of eggs of *T. absoluta*, between 92 and 96% when releasing 8 or 12 first stage nymphs of *N .pseudoferus* per plant and cause 91.7 % of damage reduction was obtained when releasing 30 adults/ plant (=75 adults/m^2) every 3-4 days (Cabello *et al*., 2009). In Sudan, three species belonging to the family Braconidae; Bracon *(Habrobracon) sp. Concolorans Marshall*, *Bracon (Habrobracon) hebetor Say* and *Torymidae ecdamuacadenati* (Risbec), were reported as potential parasitoids of *T. absoluta*. Also *Macrolophus* sp. and *N. tenuis* were found very efficient predatory bugs preying on eggs and larvae of the pest. (Mahmoud etal., 2020). In laboratory study, Idriss et al., 2018 stated that, *Bracon nigricans Szépligeti (Braconidae)* and *Dolichogenidea* *appellator (Telenga)* (Braconidae) are potential parasitoids of different larval instars of *T. absoluta* in Sudan.

2.2.11.6 Microbial control

Bacillus thuringiensis var. Krustaki has exhibited reasonable mortality to larvae of *T. absoluta* in Spain also It is reported that in a combine application of*B. thuringiensis* and mass release of *Trichogramma pretiosum* resulted in only 2% fruit damage in South America (Medeiros *et al*., 2006). Entomopathogenic fungus *Metarrhizium anisopliae* was found to cause female's mortality up to 37.14%. Laboratory studies indicated that, *Beauveria bassiana* could cause 68% larval mortality (Anonymous, 2015).

2.2.11.7 Botanical insecticides

Many plant materials were found effective against several pests, comparatively harmless to natural enemies, cheap easy to prepare and contain multiplicative components more than most of the commonly used synthetic insecticides (Gontijo *et al*., 2015). Over two thousand plant species are reported to have insecticidal properties (Shivakumar *et al*., 2013) Azadirachtin obtained up to 92 % of mortality to larvae of *T. absoluta*. High mortality was obtained with insecticides of plant origin like Azadirachtin (El-ghany *et al*., 2016,Yalçin *et al*., 2015), In Sudan, Neem, *Azadirachta indica*, Garlic *Allium sativum*, *Argel solenostemma* sp., *Coriander coriandrum*, *Sativum* spp and *Khella ammivisnaga* (L.) proved their high potency in reducing infestation of tomato fruit by *T. absoluta* and increased yield (Mahmoud *et al*., 2020). Also, other studies have shown higher bioactivity of extracts from some plants such as *Acmella oleracea*

(Asteraceae) and *Thymus vulgaris* (Lamiaceae) against *T. absoluta* larvae (Morena*et al*., 2012; Nilahyane *et al*., 2012. Finding indigenous plant species with insecticidal properties along with a simple preparation technology would benefit more local poor farmers.

2.2.11.8 Integrated management of *T. absoluta*

T. absoluta is one of those insects requiring more than one practice to be used at a time, to attain successful control (Daniel and Bajarahg 2017). Moreover, some insects may be controlled by a combination of practices that are each not fully effective when used separately. IPM strategies are being developed in South America to control *T. absoluta*. Various active substances can be applied in combination with bio – rationale control tactics. The integrated control method recommended employs, in order, massive trapping before planting, clearing the soil of crop residues, the application of lmidacloprid in the irrigation water 8 – 10 days after planting, the application of either Spinosad or Indoxacarb if occasional individuals of *T. absoluta* are observed, and elimination of the remnants of the crop immediately after the last fruits have been harvested (Roberdo Junco *et al*., 2008). In case of pheromone trap catches more than ten moths per trap per week control treatments are recommended to be carried out mainly with bio-rational products, such as *Bacillus thuringiensis* and Azadirachtin. In low population densities mass trapping of the pest with pheromone baited water traps has also proved to be an effective control measure in Spanish outbreak. An Average of 30-40 pheromone baited water traps should be placed per hectare. Mass trapping provide an environmentally friendly control measure which is sustainable, safe and effective (Anonymous,2015).

CHAPTER THREE

MATERIALS AND METHODS

3.1. Evaluation of tomato accessions and hybrids to the infestation of *T. absoluta*:

Twelve Sudanese accessions and 4 hybrids of tomato were evaluated for their susceptibility to the infestation by the South American tomato moth *T. absoluta.* The study was conducted for three consecutive seasons (2017-2018, 2018- 2019 and 2019- 2020) at Takroof area, Kassala and Gash Research Station (KGRS) farm, Kassala, Sudan(Plate3).Tomato accessions used in this study were provided by the Plant Genetic Resources Center (PGRC) of the Agricultural Research Corporation (ARC), Sudan (Table.1) while the 4 hybrids used for the comparison; are widely used by farmers in Kassala State, and were brought from the market. In each season, seeds of the tomato accessions and hybrids were sown in the Nursery of KGRS in October prior to their transplanting in the field in November. The land was ploughed, harrowed, leveled and allocated to plots measured (3×4) m^2 with two beds (Mastaba, 3×1,4 m), Plants were sown on both sides of the bed and intra row spacing was 0.6m and inter row spacing was 0.3 m between plant holes. Also all cultural practices including hand weeding, irrigation, and fertilization were applied according to the ARC recommendations.

PlateNo.3: Location of the present study (Takroof area)

Table A. Plant accessions used in the study

Entry	Name	Sources
1	HSD 10687	PGRC of ARC
2	HSD 11429	PGRC of ARC
3	HSD 6069	PGRC of ARC
4	HSD 4912	PGRC of ARC
5	HSD 4460	PGRC of ARC
6	HSD 10665	PGRC of ARC
7	HSD 6639	PGRC of ARC
8	HSD 14358	PGRC of ARC
9	HSD 6071	PGRC of ARC
10	HSD 4419	PGRC of ARC
11	HSD 4420	PGRC of ARC
12	HSD 10689	PGRC of ARC
13	Local check (Amani)	Local market
14	Local check (Insaf)	Local market
15	Local check (Jaguar)	Local market
16	Local check (Amal)	Local market

Source: Plant Genetic Resources Centre (PGRC)

Agricultural Research Corporation (ARC)

Horticulture Sudan (HSD)

3.2 Experimental design:

The trial was laid in a Randomized Complete Block Design (RCBD) comprising of 16 treatments and each treatment was replicated three times. From each replicate, five plants were selected randomly and checked for the presence of larval stage or the infestation of tomato by leaf miner, *T. absoluta.* The number of life mines was counted and the percentage of infested plants was computed according to the following formula:

$$\text{Percentage of plant infestation} = \frac{\text{No. of plant infested} \times 100}{\text{Total number of plants}}$$

Five counts were carried out each season; also, days to 50% flowering of plants were counted. During harvest, tomato fruits of each accession or hybrid were picked periodically alone in paper bags and transported to the laboratory of the station. In the laboratory, number, diameter and weight of fruits were calculated. The percentage of infested fruits was determined according to the formula. In each season, fruit quality (TSS) was measured using [(ATAGO (ATC_1) Refractometer) device (Made in Japan)], and fruit yield (Ton/ha) was recorded.

3.3. Determination and count of Trichomes density of leaves of tomato accessions and hybrids

From the experiment of evaluation of accessions and hybrids of tomato against *T. absoluta*, five leaves from five plants were collected randomly from each plot. The numbers of trichomes/cm^2 were calculated under abinocular microscope for each accession and hybrid.

3.4. Determination of chemical constituents of test accessions and hybrids of tomato

Samples of fruits were collected in ventilated paper bags and transported to the chemical laboratory of Biotechnology Research Center of ARC, Khartoum, Sudan, to determine Lycopene, Tannin, Carotenoids and Ascorbic acid (Vitamin C) using Elico SL-150 UV-Vis spectrophotometer device (Plates : 4,5,6&7)applying specific protocols for each chemical content.

3.4.1. Lycopene

Extraction of Lycopene in the tomato samples with a solvent mixture of hexane: ethanol: acetone (2:1:1, v/v) was made following the Sadler *et al*,(1990) procedure for extraction, with some slight modifications. Briefly, 1g of lyophilized sample was melded with 8 ml of the solvent mixture, capped and placed on the rotary mixer, then after at least 30 min of extraction, 10 ml of distilled water was added to separate the phases, and the absorbance of lycopene level (the upper phase) was measured at 503nm after 5 min. Lycopene levels in the hexane extracts were calculated according to the formula:

Lycopene (mg/kg fresh wt.) = $(A_{503} \text{x } 537 \text{ x } 8 \text{ x } 0.55)/(1 \text{ x } 172) = A_{503} \text{x } 171.1$

Where: A_{503} is Absorbance at 503 nm , 537 g/mole is the molecular weight of lycopene, 8 mL is the volume of mixed solvent, 0.55 is the volume ratio of the upper layer to the mixed solvents, 1 g is the weight of tomato added, and 172 mM^{-1} is the extinction coefficient for lycopene in hexane (Sadler*et al*., 1990).

3.4.2. Tannin

Tannin content was determined using the modified vanillin-HCl method as described by Price *et al*. (1978). About 0.2 g of ground sample (fruit powder) was extracted with 10 ml HCl 1% for 30 min in rotary mixer, followed by filtration using Whatman No.1 filter paper, then 1ml aliquot of the supernatant was mixed with 5 ml of fresh vanillin reagent (8% HCl in methanol and 1% vanillin in methanol). The reactants were maintained at $30C^0$ and absorbance read after 20 min at 500 nm. The tannin content of the extracts was expressed as Catechin Equivalents mg/g (Price *et al*., 1978).

3.4.3. Carotenoids

Carotenoids were extracted according to the method of Jacques *et al*, (2009). Two (2) g of tomato leaves powder were weighed and homogenized with 25 ml of cold acetone. The mixture was shaked for 10 min at room temperature, followed by filtration using Whatman No. 1 filter paper. The supernatant was recovered, transferred to a decanting funnel, where a liquid: liquid extraction was carried out with 20 ml petroleum ether. To remove the acetone, the filtrate was washed with 100 ml distilled water and the lower phase was discarded. The procedure was repeated twice, and the petroleum ether layer was filtrated using Whatman No. 1 filter paper covered with 5 g of anhydrous sodium sulfate to remove residual water. The petroleum ether extracts were obtained, and the volume was adjusted to 25 mL with petroleum ether. The absorbance was measured at 450 nm to determine the total carotenoid content using the following formula:

$$\text{Total carotenoids } (\mu g\ \beta\text{--carotene } g{-}1) = (A \times V \times 10^4) / E1\%_{1cm} \times P$$

where A Absorbance at 450 nm, V Total extract volume, P Sample weight and $E^{1\%}_{1cm}$ Extinction coefficient of β-carotene in petroleum ether = 2592 following (Jacques *et al*., 2009).

3.4.4. Vitamin C

Vitamin C in tomato samples was measured via a titration method using the 2,6-dichloroindo phenol indicator dye according to the AOAC method. three grams of each sample were blended with 0.4% oxalic acid and filtered, and the volume was adjusted to 100 mL with oxalic acid. A volume of 10 mL was added to 5 mL of 10% oxalic acid and titrated against 2,6-dichlorophenol indophenol dye (AOAC, 2005).

The Instruments used in chemical analysis

Plate No.4: Spectrophotometer (measure chemical compounds in a sample).

Plate No.5: Centrifuge (separating samples)

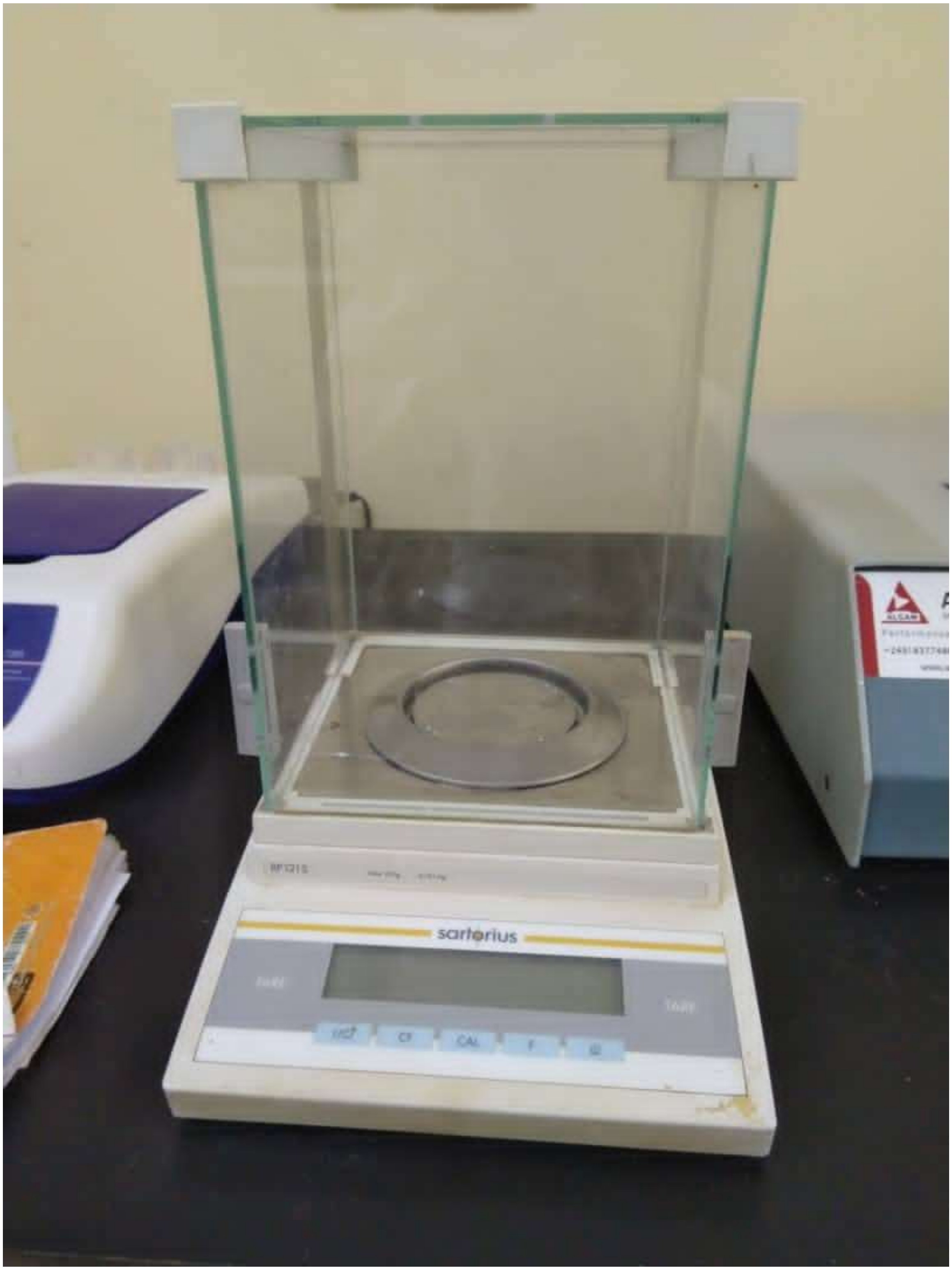

Plate No.6: Sensitive Balance (samples weight)

Plate No.7: Shaker (shake and mix the samples).

3.5. Field evaluation of Neem oil *Azadirachta indica A. Juss* and aqueous extracts of leaves of periwinkle, *Vinca rosea L.*, and *Datura stramoniumn, L* against *T. absoluta*

3.5.1 Layout of the experiment

The experiment was conducted at the experimental farm of Kassala and Gash Research Station, (Takroof area), Kassala State, Sudan during the winter season (2019/2020). The tomato accession HSD 10655 provided by Plant Genetic Resource Center of the Agricultural Research Corporation was sown in the nursery of the station in October prior to be transplanted in the field in November. The land was ploughed, harrowed, leveled and allocated to plots measured ($3x4m^2$) with two beds (Mastaba, $3x1.4m^2$). Plants were sown on both sides of the bed an intra row spacing was 0.6m and inter row spacing was 0.3m between plant holes. All cultural practices were followed as ARC standards.

3.5.2 Collection of plant materials and preparation of extracts:

Seeds of Neem *Azadirchta indica A. Juss*and leaves of periwinkle, *Vinca rosea L.*, and Datura, *Datura stramoniumn, L* were collected from Kassala Research Farm where they grow naturally. Leaves of Vinca and Datura were dried under shade to prevent denaturation of active chemicals. After preparation, 100gm of powder leaves were mixed in 100 liters of water, the powder was left in boiled water for 20 minutes and left for 24 hr. to dry, then filtered with muslin cloth and was kept as a stock solution for later use.

For extraction of Neem seed oil, Neem seeds were soaked in water for 12 hours and were manually decorticated then left for 24 hours to dry under shaded area. Decorticated Neem seeds were pressed in local-made expeller to produce oil.

3.5.3 Field observations

A randomized complete block design (RCBD) was used to lay out the experiment which consisted of five treatments and each treatment was replicated thrice. Treatments included Neem seed oil (0.72 L/ha), water extract of Vinca (0.96 L/ha) water extract of Datura (0.96 L/ha), Dancid 15% EC (0.48 L/ha); standard chemical insecticide, and untreated control were allocated randomly on already prepared plots. All test materials were applied before sunset 3 times (with one week interval) during the cropping season using pneumatic knapsack sprayer. Pre and post spray counts were conducted and data for insect parameters caused by *T. absoluta* were compiled during vegetative and harvesting periods , which included:

3.5.3.1 Percentage of tomato infested plants/plot

From each plot 20 plants were randomly selected and inspected for the presence of symptoms of *T. absoluta* infestation.

3.5.3.2 Number of active mines of *T. absoluta* on leaves/ plot

Numbers of active mines that contain live larvae of *T. absoluta* were determined by inspection of 5 leaves from 5 plants randomly selected from each plot.

3.5.3.3 Percentage (%) of fruits damaged by *T. absoluta*

On harvesting time, fruits were harvested and separated to damaged and healthy, The percentage of damaged fruits was calculated according to the following formula:

$$\text{Percentage of fruit infestation} = \frac{\text{No. of fruit infested}}{\text{Total number of fruits}} \times 100$$

The three above mentioned parameters were assessed pre spray of test materials and also were assessed after 48h, 72h and a week post spray.

Yield assessment: Yield of tomato of different treatments (Ton/Ha) was calculated.

3.6 Statistical analysis

For all experiments, analysis of variance (ANOVA) was used to determine the difference between accessions and hybrids for the different studied traits. Also, Complete Data were analyzed using SAS Statistical Computer Program (Version 9) and means were separated using Duncan's Multiple Range Test (DMRT). In the experiment of evaluation of accessions and hybrids against *T. absoluta*, Data of days to 50% flowering, number of infested plants/plot, percentage of infested fruits as well as yield per hectare were transformed when needed. Pearson' Correlation between different studied parameters was also conducted.

CHAPTER FOUR

RESULTS

4.1. Evaluation of tomato accessions and hybrids to the infestation of *T. absoluta*

4.1.1 Days to 50% flowering of some tomato accessions evaluated against infestation by tomato leaf miner *T. absoluta*

Results presented in (Table 1, Fig 1) proved that, there is no significant difference between the accessions and hybrids of tomato in the number of days to 50% flowering for the first season (2017-2018), the third season (2019-2020) and the combined analysis of the data of the three seasons. But high significant difference (pr > f<0001) was recorded for the second season (2018-2019), also it was reported among seasons (pr>f<0001) and significant (pr> f<0.04) between the interaction of seasons and accessions. The accessions HSD 6071, HSD 14358 and HSD 11429 (Plate.8) were taking minimum period for first days to 50% flowering, obtained 69.2, 69.4 and 69.7, respectively in the second season. The number of days to 50% flowering correlated very weak positively with percentage of infested plants/plot (0.26975, 0.0011), number of active mines/plant (0.26455, 0.0014) and percentage of infested fruits (0.21820, 0.0086) and correlated very week negatively with yield (Ton/Ha) (-0.19129, 0.0216).

Plate No.8: Indeterminate growth and flowering for some tomato accession (HSD 11429).

Table (1): Mean Number of days to 50% flowering of some tomato accessions evaluated to infestation by Tomato leaf miner in Kassala State, Sudan for three consecutive seasons

Accessions	Days to 50% tomato flowering			Combined
	2017-2018	2018-2019	2019-2020	
HSD 10687	71.0	71.7 B	74.7	72.5
HSD 6069	68.7	73.3 B	76.3	72.8
HSD 4912	71.0	73.3 B	78.0	74.1
HSD 4460	73.3	73.3 B	74.7	73.3
HSD 10665	66.3	75 A	74.7	72.0
HSD 6639	71.0	71.7 B	78.0	73.6
HSD 4419	68.7	75 A	74.7	72.8
HSD 4420	68.7	71.7 B	74.7	71.7
HSD 10689	71.0	68.3 B	76.3	71.9
HSD11 429	66.2	68.3 B	74.3	69.7
HSD 6071	66.3	68.3 B	73.0	69.2
HSD 14358	68.7	66.7 B	73.0	69.4
Amani	75.7	66.7 B	74.3	73.3
Insaf	75.7	71.7 B	73.0	73.4
Jaguar	75.7	71.7 B	73.0	73.4
Amal	68.7	71.7 B	73.0	71.1
C.V	7.1	3.8	3.0	4.8
Pr> F accession	0.3	<.0001	0.2	0.0496
Pr> F Seasons	0.2911	0.0052	0.1188	<.0001
Pr> F Seasons*accessions				0.0364
Std Error	0.7	0.5	0.4	0.9

Means followed by the same latter (s) were not significantly different at ($P \leq 0.05$)

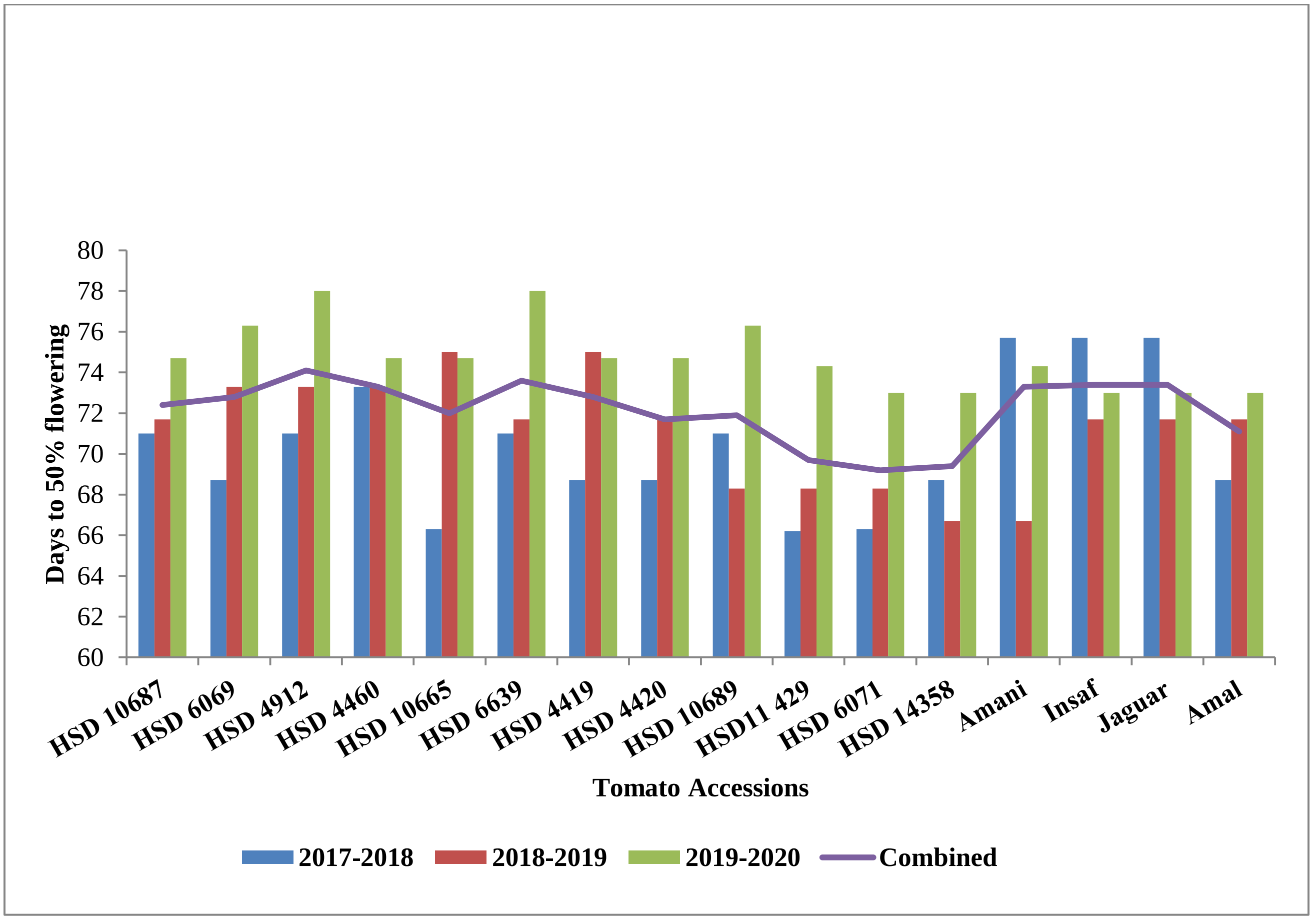

Figure (1): Mean days to 50% tomato flowering of some tomato accessions evaluated to infestation by tomato leaf miner in Kassala state, Sudan for three consecutive seasons.

4.1.2. Percentage of plants infested by tomato leaf miner *T. absoluta* of different tomato accessions and hybrids

For the three consecutive seasons of the study,their combined analysis revealed high significant differences (Pr> F <.0001) between the percentages of infested plants for all counts of the tested local accessions and hybrids of tomato (Tables 2, 3,4,5 and Figure 2.). Also,highsignificance among seasons (Pr> F<.0001)and also among the interaction between accessions and hybrids and seasons (Pr> F<.0001). Accessions HSD11429, HSD 6071 and HSD 14358 with 5.6, 5.3 and 5.3 infested plants/plot respectively were found the least infested plants/plot when compared to the other accessions and hybrids that were ranged between 31.2 and 42.6 infested plants/plot as shown in (Table 5 and Figure 2). The number of plants infested by *T. absoluta* form the tested tomato accessions and hybrids was found highly positive correlated with the number of mines/plant (0.95964, <.0001), infested fruits (0.86667, <.0001), while highly negative correlation for the same parameter was observed to TSS (-0.82977, <.0001) and yield (-0.76520, <.0001).

Table (2): Mean percent of plants infested by tomato leaf miner *T. absoluta* from different tomato accessions in Kassala State, Sudan season, (2017-2018)

Accession	Count 1	Count 2	Count 3	Count 4	Count 5	Mean of all counts
HSD 10687	24.4 BA	31.6 BDAC	36.6 BA	30.4 BC	45.4 BC	35.5 BC
HSD 6069	26.5BA	28.7 DC	36.5 BA	42.6 BAC	52.8 BA	37.9 BA
HSD 4912	25.2 BA	29.2 BDC	35.7 BA	41.1 BAC	47.6 BAC	37.7 BA
HSD 4460	29.0A	33.4 BAC	40.1 A	45.3 BA	51.9 BAC	38.1 BA
HSD 10665	31.3A	36.433 BA	41.9 A	46.7 A	54.3 BA	42.2 A
HSD 6639	25.1 BA	32.0 BDAC	38.2 BA	43.4 BAC	47.9 BAC	37.3 BAC
HSD 4419	25.6 BA	32.1 B DAC	38.1 BA	41.9 BAC	52.8 BA	39.1 BA
HSD 4420	27.4 BA	31.5 BDAC	37.4 BA	44.4 BAC	54.2 BA	38.9 BA
HSD 10689	18.3 B	25 D	32.7 B	37.5 C	42.8 C	31.3 C
HSD11 429	2.53 C	6.3 E	6.9 C	7.3 D	7.6 D	6.1 D
HSD 6071	4.4 C	6.2 E	6.9 C	7.2D	7.5 D	6.5 D
HSD 14358	2.5 C	6.2 E	6.8 C	7.3 D	7.6 D	6.1 D
Amani	30.7 A	35.7 BAC	39.8 A	45 B A	49.6 BAC	38.9 BA
Insaf	33.7 A	36.9 A	41.9 A	46.6 A	54.1 BA	42.6 A
Jaguar	32.4 A	37.1 A	41 3 A	46 B A	55.9 A	42.6 A
Amal	27.9 BA	33.8 BAC	40.5 A	45 B A	50.8 BAC	39.7 BA
C.V	14.8	8.6	6.4	6.4	7.63	6.4
Pr> F	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Std Error	1.5	1.6	1.8	2.1	2.5	1.9

Means followed by the same latter (s) were not significantly different at ($P \leq 0.05$)The data were transformed to Arcsine whenneeded.

Table (3): Mean percent of plants infested by tomato leaf miner *T. absoluta* from different tomato accessions in Kassala State, Sudan Season, (2018-2019)

Accession	Mean infested plants/plot					
	Count 1	**Count 2**	**Count 3**	**Count 4**	**Count 5**	**Means of all counts**
HSD 10687	23.9 B A C	29.9 B	34.5 BA	38.1 BC	45.8 BA	34.4 BDC
HSD 6069	25. B A C	30.2 B A	38.4 A	43.3 BA	47.1 BA	36.8 BAC
HSD 4912	27.2 B A C	29.6 B	34.8 BA	43.1 BA	48.7 BA	37.4 BAC
HSD 4460	26.4 B A C	32.2 B A	38.9 A	46 BA	54.8 A	39.7 BAC
HSD 10665	27.2 B A C	30.4 B A	35.5 BA	38.9 BAC	45.7 BA	35.5 BDC
HSD 6639	25.9 B A C	31.6 B A	37.6 BA	39.7 BAC	45.5 BA	36.1 B DC
HSD 4419	25.9 B A C	33.8 B A	40.9 A	46.4 BA	52.7 BA	39.9 BA
HSD 4420	29.3 B A	33.4 B A	38.8 A	42.5 BAC	49.8 BA	38.8 BAC
HSD 10689	20.1 C	27.5 B	29.9 B	33.8 C	42.5 B	30.8 D
HSD11 429	3.5 D	5.3 C	5.7 C	6.7 D	7.2 C	5.6 E
HSD 6071	0.7 D	4.9 C	5.4 C	6.1 D	6.7 C	4.7 E
HSD 14358	2.1 D	3.5 C	5.7 C	6.7 D	7.3 C	5.1 E
Amani	30.5 A	36.7 A	41 A	47.4 A	54.9 A	42.1 A
Insaf	28.8 B A	32.6 B A	36.8 BA	42.2 BAC	49.7 BA	38 BAC
Jaguar	27.5 B A	32.3 B A	39.8 A	44.4 BA	54.1 A	39.4 BAC
Amal	22.7 B C	27.7 B	35.9 BA	39.4 BAC	44.7 BA	34.1 D C
C.V	10.7	8.1	8.6	8.3	8.7	5.9
Pr> F	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Std Error	1.4	1.6	1.9	2.1	2.5	1.9

Means followed by the Arcsine value tables same latter (s) were not significantly different at ($P \leq 0.05$)The data were transformed to Arcsine when needed.

Table (4): Mean percent of plants infested by tomato leaf miner *Tuta absoluta* from different tomato accessions in Kassala State, Sudan Season (2019-2020)

Accessions	Mean infested plants/plot					
	Count 1	Count 2	Count 3	Count 4	Count 5	Means of all counts
HSD 10687	24.2 BA	31.3 BA	35.5 BAC	37.6 BC	42.3 BC	34.2 BC
HSD 6069	24.5 BA	30.2 BA	37.3 BAC	43.4 BA	49.3 BAC	36.9 BAC
HSD 4912	21.4 BA	29.8 BA	34.8 BC	41.5 BAC	47.9 BAC	35.1 BC
HSD 4460	22.2 BA	28.1 B	32.3 BC	37.2 BC	43.8 BAC	32.8 BC
HSD 10665	30.8 A	36.7 A	42.5 A	47.1 A	43.4 BAC	42.6 A
HSD 6639	20.6 B	27.5 B	35.9 BAC	38.8 BAC	51.0 BA	32.2 BC
HSD 4419	24.8 BA	31.3 BA	35.6 BAC	40.6 BAC	51.0 BA	37.3 BA
HSD 4420	22.9 BA	27.5 B	35.3 BC	42.9 BA	55.0 A	36.7 BAC
HSD 10689	19.2 B	26.6 B	34.1 BC	36.1 BC	40.8 BC	31.4 C
HSD11 429	1.9 C	4.7 C	5.5 D	5.9 D	6.5 D	4.9 D
HSD 6071	2.2 C	3.6 C	5.3 D	6.1 D	6.5 D	4.7 D
HSD 14358	1.9 C	3.6 C	5.4 D	5.8 D	6.9 D	4.8 D
Amani	26.2 BA	34.0 BA	37.8 BA	42.7 BA	48.7 BAC	37.9 BA
Insaf	24.6 BA	29.6 BA	32.7 BC	39.8 BAC	45.2 BAC	34.4 BC
Jaguar	26.7 BA	31.2 BA	35.2 BC	40.1 BAC	50.6 BA	36.7 BAC
Amal	25.1 BA	28.3 B	30.6 C	33.6 C	37.7 C	31.1 C
C.V	15.9	10	7.8	8.1	10.1	6.5
Pr> F	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Std Error	1.4	1.6	1.8	2	2.4	1.8

Means followed by the same latter (s) were not significantly different at ($P \leq 0.05$). The data were transformed to Arcsine when needed.

Table (5): Combined analysis of the mean percentage of plants infested by tomato leaf miner *T. absoluta* on some tomato accessions in Kassala State, Sudan (Three consecutive Seasons (2017-2018, 2018-2019 and 2019-2020).

Accessions	Means					
	Count 1	**Count 2**	**Count 3**	**Count 4**	**Count 5**	**Means of all counts**
HSD 10687	24.2 DC	30.9 BC	35.6 BDC	38.4 DE	44.5 DC	34.7 E
HSD 6069	25.3 BDAC	29.7 DC	37.4BAC	43.1 BAC	49.7 BAC	37.2 EBDAC
HSD 4912	24.6 BDC	29.5 DC	35.1 DC	41.9BDAC	48.1BDAC	36.7 EBDC
HSD 4460	25.9 BDC	31.2 BC	37.1 BAC	42.9 BAC	50.2 BAC	36.9EBDAC
HSD 10665	29.8 A	34.5 BA	39.9 A	44.3 BDC	50.9 BA	40.1 A
HSD 6639	23.9 DE	30.4 DC	37.3 BAC	40.6 BDC	45.6 BDC	35.5 EDC
HSD 4419	25.4BDAC	32.4BAC	38.2 BAC	42.9 BAC	52.2 A	38.4 BAC
HSD 4420	26.6 BDAC	30.8 BC	37.2 BAC	43.3 BAC	53.0 A	38.2 BDAC
HSD 10689	19.2 E	26.4 D	32.2 D	35.8 E	42.0 D	31.1 F
HSD11 429	2.7 F	5.4 E	6.1 E	6.6 F	7.1 E	5.6 G
HSD 6071	2.4 F	4.9 E	5.9 E	6.4 F	6.9 E	5.3 G
HSD 14358	2.2 F	4.5 E	5.9 E	6.6 F	7.3 E	5.3 G
Amani	29.1 BA	35.5 A	39.5 BA	45.1 A	51.1 BA	39.6 BA
Insaf	29.1 BA	33.0 BAC	37.2 BAC	42.9 BAC	49.6 BAC	38.3 BAC
Jaguar	28.9 BAC	33.5 BAC	38.8 BAC	43.5 BAC	53.5 A	39.6 BA
Amal	25.3 BDAC	29.9 DC	35.7 BDC	39.3 DEC	44.4 DC	34.9 ED
C.V	137	9.3	7.8	7.6	9.2	6.3
Pr> F Seasons	<.0001	<.0001	<.0001	<.0001	0.0001	<.0001
Pr> F varieties	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Pr>F Season*Varietiess	0.1361	0.0075	0.0001	0.0002	0.0376	<.0001
SE ±	0.84	0.91	1.1	1.2	1.4	1.1

Means followed by the same latter (s) were not significantly different at ($P \leq 0.05$) The data were transformed to Arcsine when needed.

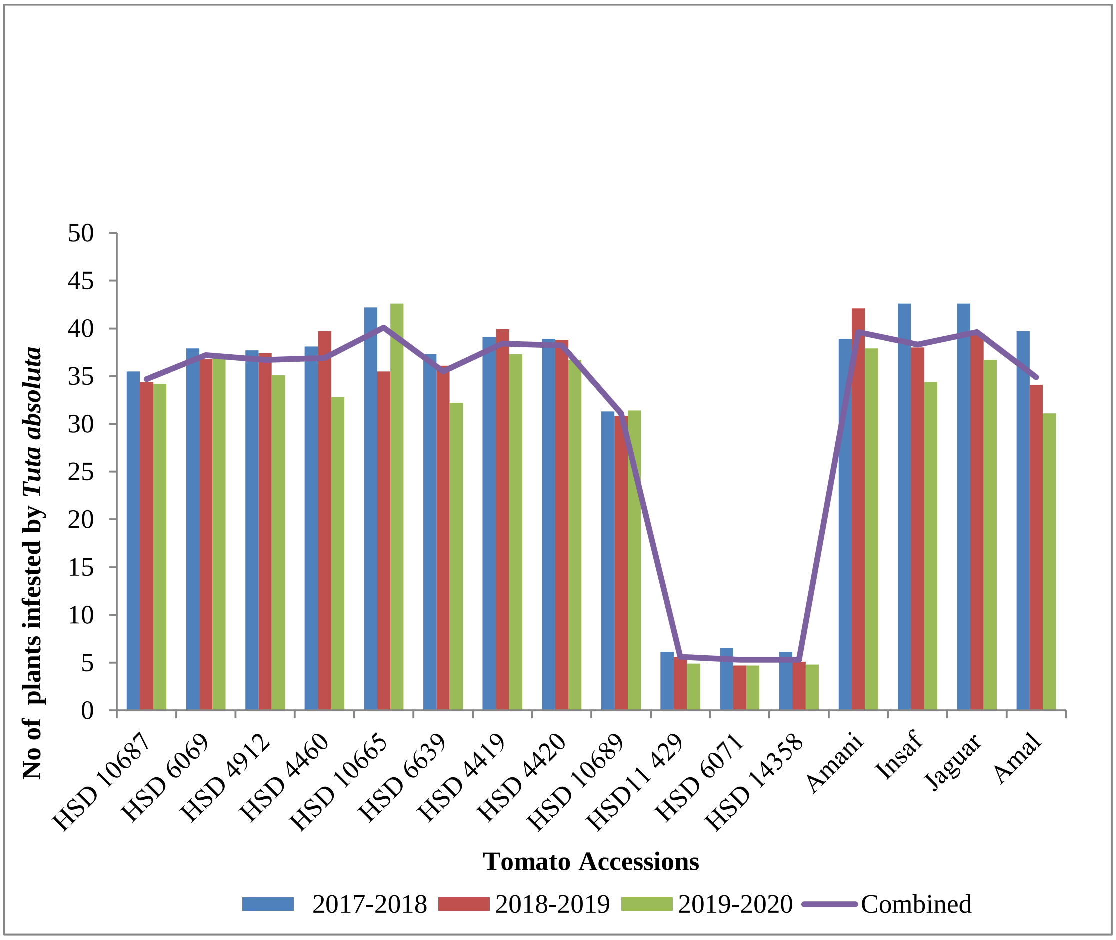

Figure (2): Mean percent of plant infestation by tomato leaf miner *T.absoluta* on some tomato accession in Kassala State, Sudan for three consecutive seasons (2017– 2018, 2018-2019 and 2019-2020) and their combined analysis .

4.1.3. Number of life mines caused by tomato leaf miner *T. absoluta* for different tomato accessions and hybrids

High significant differences (pr > f <0001) were observed between the number of life mines (contain life larva) for all counts for the tested local accessions and hybrids of tomato for the three consecutive seasons of this study (Tables 6,7,8). Also, combined analysis of the three seasons showed high significant differences between the accessions and hybrids (pr>f < 0001) among seasons (pr > f >0.01) and no significant differences were recorded between interaction of accessions and hybrids and seasons (pr > f > 0.1) (Table 9). The accessions HSD 11429, HSD 6071 and HSD 14358 were found the least mean life mines / plots, with 5.0, 4.9 and 4.9 mines / plot respectively (plate.9). While the other accessions and hybrids recorded highest number of life mines ranged between (19.2 and 25.9) life mines / plots as shown in (Table 9 and Figure 3). The correlation analysis revealed high negative correlation between the number of life mines and TSS (-0.84764, <.0001) and yield (-0.74567, <.0001)

Table (6): Mean number of life mines caused by tomato leaf miner *T. absoluta* on tomato accessions during the Kassala State, Sudan Season (2017-2018)

Accession	Means					
	Count 1	**Count 2**	**Count 3**	**Count 4**	**Count 5**	**Means of all counts**
HSD 10687	16.3 BA	17.7 E D	20.5 DE	23.3 DC	25.1 C	20.8 DE
HSD 6069	16.7 BA	19.1EDC	22.2BDE C	25.6 BDAC	28.4BAC	22.4 BDEC
HSD 4912	16.7 BA	20.5BDC	23.8BDA C	27.1 BAC	30.2 BA	23.7 BDAC
HSD 4460	18.1 BA	20.8BDC	24.3 BEAC	26.3 BDAC	29.9BA	24.6 BAC
HSD 10665	19.7 BA	22.7BAC	25.6 BA	29.5 A	32.1 A	25.9 BA
HSD 6639	17.1 BA	19.0EDC	21.6 DEC	24.1 BDC	27.9 C	21.9 DEC
HSD 4419	16.3 BA	19.9BEDC	23.8BDAC	26.8 BAC	30.2BA	23.4 BDAC
HSD 4420	19.4 BA	22.5BAC	25.9 BA	28.9 A	31.9 A	25.7 BA
HSD 10689	14.9 B	16.7 E	19.3 E	22.2 D	24.6 C	19.5 E
HSD11 429	2.3 C	5.5 F	6.0 F	6.5 E	6.8 D	5.5 F
HSD 6071	3.7 C	5.5 F	5.9 F	6.4 E	6.9 D	5.7 F
HSD 14358	2.3 C	5.8 F	6.2 F	6.6 E	7.2 D	5.6 F
Amani	21.1 A	24.6 A	26.5 A	28.2 D A	31.1 B A	26.3 A
Insaf	19.4BA	22.5 BAC	26.5 A	27.9 B A	31.1 B A	25.5 BAC
Jaguar	20.8 A	23.3 BA	25.4 BAC	29.0 A	31.5 B A	25.9 BA
Amal	20.2 A	22.8 BA C	25.3 BAC	28.4 A	31.9 A	25.7 BA
C.V	11.3	6.9	6.4	5.9	5.0	5.9
Pr> F	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Std Error	0.9	0.9	1.07	1.2	1.3	1.1

Means followed by the same latter (s) were not significantly different at ($P \leq 0.05$)..

Table (7): Mean number of life mines caused by tomato leaf miner *T. absoluta* on tomato accessions in Kassala State, Sudan Season (2018-2019)

Accession	Means					
	Count 1	Count 2	Count 3	Count 4	Count 5	Means of all counts
HSD 10687	23.9 BAC	29.9 B	34.5BA	38.1 BC	45.8 BA	34.4 BDC
HSD 6069	25. BAC	30.2 BA	38.4 A	43.3 BA	47.1 BA	36.8 BAC
HSD 4912	27.2 BAC	29.6 B	34.8 BA	43.1 BA	48.7 BA	37.4 BAC
HSD 4460	26.4 BAC	32.2 BA	38.9 A	46 B A	54.8 A	39.7 BAC
HSD 10665	27.2 BAC	30.4 BA	35.5 BA	38.9 BAC	45.7 BA	35.5 BDC
HSD 6639	25.9 BAC	31.6 BA	37.6 BA	39.7 BAC	45.5 BA	36.1 BDC
HSD 4419	25.9 BAC	33.8 BA	40.9 A	46.4 BA	52.7 BA	39.9 BA
HSD 4420	29.3 BA	33.4 BA	38.8 A	42.5 BAC	49.8 BA	38.8 BAC
HSD 10689	20.1 C	27.5 B	29.9 B	33.8 C	42.5 B	30.8 D
HSD11 429	3.5 D	5.3 C	5.7 C	6.7 D	7.2 C	5.6 E
HSD 6071	0.7 D	4.9 C	5.4 C	6.1 D	6.7 C	4.7 E
HSD 14358	2.1 D	3.5 C	5.7 C	6.7 D	7.3 C	5.1 E
Amani	30.5 A	36.7 A	41 A	47.4 A	54.9 A	42.1 A
Insaf	28.8 BA	32.6B A	36.8 BA	42.2 BAC	49.7 BA	38 BAC
Jaguar	27.5 BA	32.3B A	39.8 A	44.4 BA	54.1 A	39.4 BAC
Amal	22.7 BC	27.7 B	35.9B A	39.4 BAC	44.7 BA	34.1 DC
C.V	10.7	8.1	8.6	8.3	8.7	5.9
Pr> F	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Std Error	1.4	1.6	1.9	2.1	2.5	1.9

Means followed by the same latter (s) were not significantly different at (P≤0.05.

Table (8): Mean number of life mines caused by tomato leaf miner *T. absoluta* on tomato accessions during the Kassala State, Sudan Season (2019-2020**)**

Accession	Means					
	Count 1	**Count 2**	**Count 3**	**Count 4**	**Count 5**	**Means of all counts**
HSD 10687	15.2 BAC	18.3 A	21.2 BA	25.8 BAC	30.2 A	22.1 BAC
HSD 6069	13.9 DC	19.6 A	23.4 BA	25.9 BAC	31.0 A	22.8 BAC
HSD 4912	17.4 BA	16.2 A	23.6 BA	25.6 BAC	28.8 B A	22.7 BAC
HSD 4460	17.0 BAC	18.5 A	25.6A	27.5 BA	31.9 A	24.1 BA
HSD 10665	14.7 BAC	19.6 A	23.3 BA	25.6 BAC	30.4 A	22.7 BAC
HSD 6639	14.3 BAC	19.2 A	22.4 BA	25.6 BAC	28.9 BA	22.1 BAC
HSD 4419	14.1 BAC	17.8 A	20.8 BA	23.8 BC	27.7 BA	20.8 BC
HSD 4420	13.9 DC	19.5 A	21.6 BA	26.0 BAC	30.2 A	22.3 BAC
HSD 10689	11.9 C	15.9 A	18.4 B	20.9 C	23.0 B	18.0 C
HSD11 429	3.1 D	4.5 B	5.1 C	5.6 D	5.2 C	4.7 D
HSD 6071	2.9 D	4.3 B	4.9 C	5.2 D	5.7 C	4.6 D
HSD 14358	2.8 D	4.2 B	4.7 C	4.9 D	5.3 C	4.4 D
Amani	17.0 BAC	20.5 A	24.6 BA	29.1 BA	33.8 A	25.0 BA
Insaf	18.7 BA	22.8 A	26.5 A	29.8 BA	32.6 A	26.1 BA
Jaguar	19.6 A	22.9 A	27.2 A	30.0 A	33.6 A	26.7 A
Amal	19.1 BA	21.7 A	23.3 BA	27.9 B	31.9 A	24.8 BA
C.V	13.4	17.2	11.3	9.1	8.5	8.8
Pr> F	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Std Error	0.8	1.0	1.1	1.3	1.5	1.1

Means followed by the same latter (s) were not significantly different at ($P \leq 0.05$).

Table (9): Combined analysis of number of life mines caused by tomato leaf miner *T. absoluta* on some tomato accessions in Kassala State, Sudan for three consecutive Seasons (2017-2018, 2018-2019 and 2019-2020).

Accession	Means					
	Count 1	Count 2	Count 3	Count 4	Count 5	Means of all counts
HSD 10687	16.4 BDEC	18.4 EF	21.1 ED	24.6 D	27.8 D	21.7 E
HSD 6069	15.6 DE	19.7EBDFC	22.9BDC	25.8 DC	29.1 BDC	22.6 DE
HSD 4912	17.4BDAC	19.4 EDFC	24.2BAC	26.7BDAC	30.1 BDAC	23.8 BDEC
HSD 4460	17.5BDAC	19.6EBDC	24.7 BA	27.0BDAC	30.8 BAC	24.2BDAC
HSD 10665	17.8BDAC	21.7 BDAC	24.6 BA	27.9 BAC	31.7 BA	24.8 BAC
HSD 6639	15.7 DE	19.1 EDF	21.7 EDC	24.6 D	27.8 D	21.8 E
HSD 4419	16.1 DEC	19.6EBDFC	22.9BDC	25.7 DC	28.8 DC	22.6 DEC
HSD 4420	17.1 BDC	21.2EBDC	24.1BAC	27.6 BAC	30.9 BAC	24.2BDAC
HSD 10689	13.9 E	19.7 F	19.3 E	21.9 E	24.3 E	19.2 F
HSD11 429	2.9 F	4.9 G	5.3 F	5.8 F	6.0 F	5.0 G
HSD 6071	2.8 F	4.7 G	5.3 F	5.7 F	6.2 F	4.9 G
HSD 14358	2.3 F	4.8 G	5.3 F	5.7 F	6.2 F	4.9 G
Amani	18.8 BAC	22.5 BA	25.5 BA	28.7 A	32.1 A	25.5 BA
Insaf	19.2 A	22.4 BAC	26.1 A	28.3 BA	31.4 BAC	25.5 BA
Jaguar	20.1 A	22.9 A	25.9 A	29.0 A	32.2 A	25.9 A
Amal	18.8 BAC	21.5EBDC	23.9BAC	27.4 BAC	31.3 BAC	24.6BDAC
C.V	11.8	10.7	7.95	6.8	6.2	6.5
Pr> F Seasons	0001	0.001	0.1	0.3	0.3	0.01
Pr> F varieties	0001	<.0001	<.0001	<.0001	<.0001	<.0001
Pr> F Season*Varieties	0.01	0.5	0.2	0.04	0.01	0.1
SE ±	0.5	0.5	0.6	0.7	0.8	0.6

Means followed by the same latter (s) were not significantly different at (P≤0.05).

Plate No.9:Low number of mine infestation (HSD 6071).

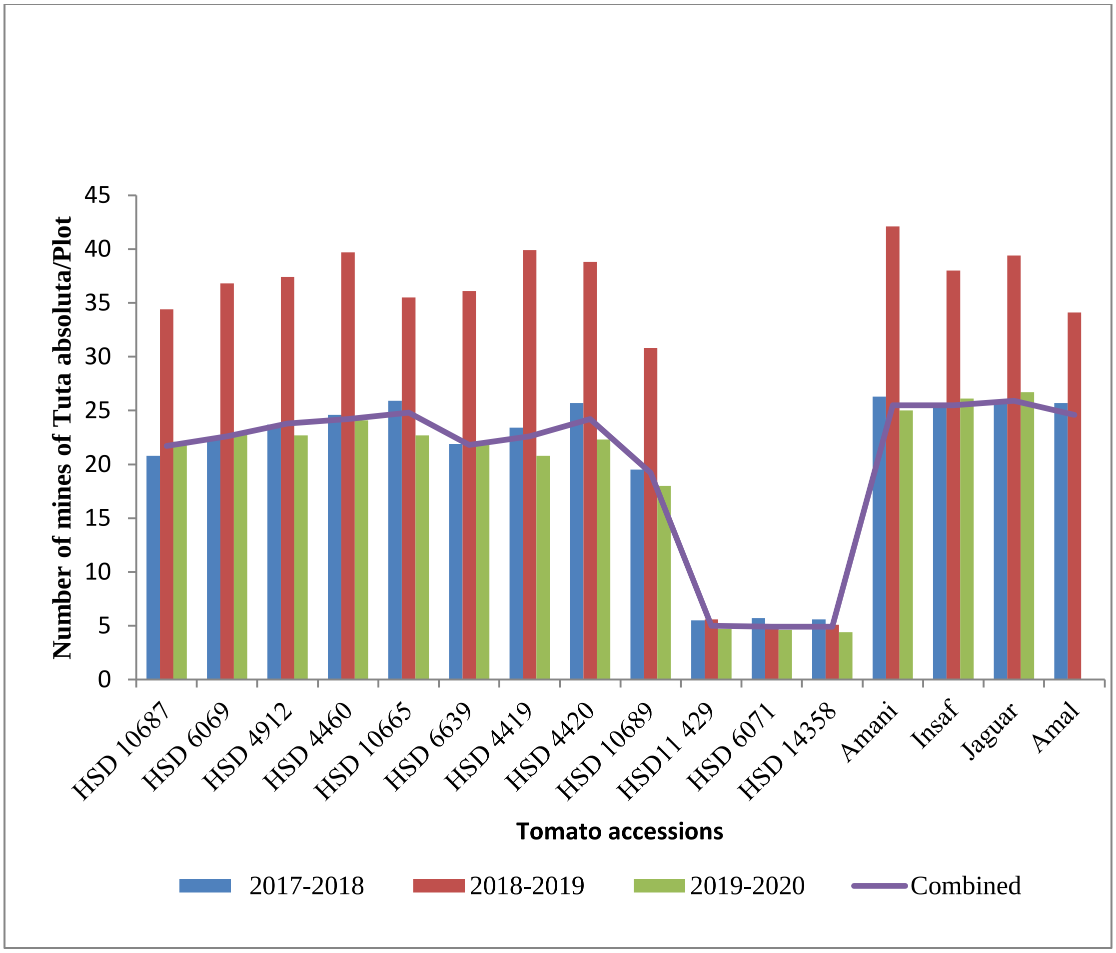

Figure (3): Mean number of mines/plot caused by tomato leaf miner *T.absoluta* on some tomato accession in Kassala State, Sudan for three consecutive Seasons (2017-2018, 2018-2019 and 2019-2020) and their combined analysis.

4.1.4. Percentage of tomato fruits infested by tomato leaf miner *T.absoluta* from different tomato accession and hybrids

As observed on the above mentioned two parameters, high significant differences (pr> f< 0001) were observed between the percentage of infested fruits/plot for all counts for the three consecutive seasons for the both tested local accessions and hybrids of tomato (Table 10).The combined analysis of the three seasons also revealed high significant difference between accessions and hybrids (pr> f< 0001) and among seasons (pr>f < 0001) while No significant difference was noticed between the interaction of accessions and seasons (pr> f< 0.2) (Table. 10 and Figure.4). The accessions HSD11429, HSD6071 and HSD14358 recorded the least percentage of infested fruits/ plot with5.9, 7.2 and 10.8% respectively, while the other accessions and hybrids recorded highest level of fruit infestation percentage ranged between 39.0 and 20.9 % of infested fruits/plot (Table. 10, plate.10). Fruit infestation percentage was found correlated high positively with number of infested plants/ plot (0.86667, <.0001) number of mines/plot (0.88661, <.0001) while correlated negatively with TSS (-0.81465, <.0001) and yield (-0.58991, <.0001).

4.1.5. Trichomes density /cm^2 of leaves of tomato

High significant difference was observed between the number of trichomes in leaves of accessions and hybrids of tomato tested against *T. absoluta* Pr > F> 0.0005. it is clear that all tested accessions are hairy than the hybrids. HSD14358 obtained the highest number of trichomes/cm^2 (5.1) followed by HSD 6071 with (4.5) trichomes/cm^2. HSD10687, HSD11429, HSD 6069, HSD 4912, HSD 4460, HSD10665, HSD 6639, HSD 4419, HSD 4420, HSD10689 was recorded the same number of trichomes/cm ca (4.3-3.2 trichomes/cm) while (2.6-2.7) trichomes/cm^2 was recorded for Insaf, Amani, Jaguar, Amal (Figure 5). The number of trichomes/cm2 of leaves was correlated highly negative with number of infested plants/plot (-0.8749, <.0001) and also with the number of mines/plot (-0.8242, <.0001) while weak positive correlation was observed between this trait and yield.

Table (10): Mean percentage of tomato fruits infested by tomato leaf miner *T.absoluta* on tomato accessions for three consecutive Seasons and their combined analysis

Accession	Percentage of infested fruits			Combined
	2017-2018	2018-2019	2019-2020	
HSD 10687	25.1 BA	30.6 CB	26.3 DC	27.3 E D
HSD 6069	32.6 BA	30.1 CBD	29.9 BC	30.9 B D c
HSD 4912	22.4 BAC	25.9 ED	22.0 D	23.4 E F
HSD 4460	30.2 BA	28.1 CB D	26.8 DC	28.4 E D
HSD 10665	34.1 A	37.9 A	36.2 A	36.1 B A
HSD 6639	26.2 B A	26.8 CED	27.5 C	26.8 E D
HSD 4419	29.4 B A	32.2 B	27.3 C	29.6 D C
HSD 4420	28.3 B A	29.8 CB D	29.8 BC	29.3 D C
HSD 10689	17.8 B C	22.7 E	22.3 D	20.9 F
HSD11 429	6.6 C	5.5 F	5.8 E	5.9 G
HSD 6071	7 C	8 F	6.6 E	7.2 G
HSD 14358	17.2 C	9.4 F	5.7 E	10.8 G
Amani	38.2 A	40.5 A	38.5 A	39.0 A
Insaf	35.4 A	36.9 A	33.7 B A	35.3 B A
Jaguar	37.1 A	40.5 A	37.5 A	38.4 A
Amal	32.4 B A	37.2 A	33.9 B A	34.5 B A C
C.V	20.4	5.4	6.4	0.01
Pr> F Accessions	<.0001	<.0001	<.0001	<.0001
Std Error	1.5	1.5	1.5	12.4
Pr> F Seasons				<.0001
Pr> F Season*Varieties				0.2

Means followed by the same latter (s) were not significantly different at ($P \leq 0.05$). The data were transformed to Arcsine when needed .

Plate No.10: High fruit infestation (hybrid Amani).

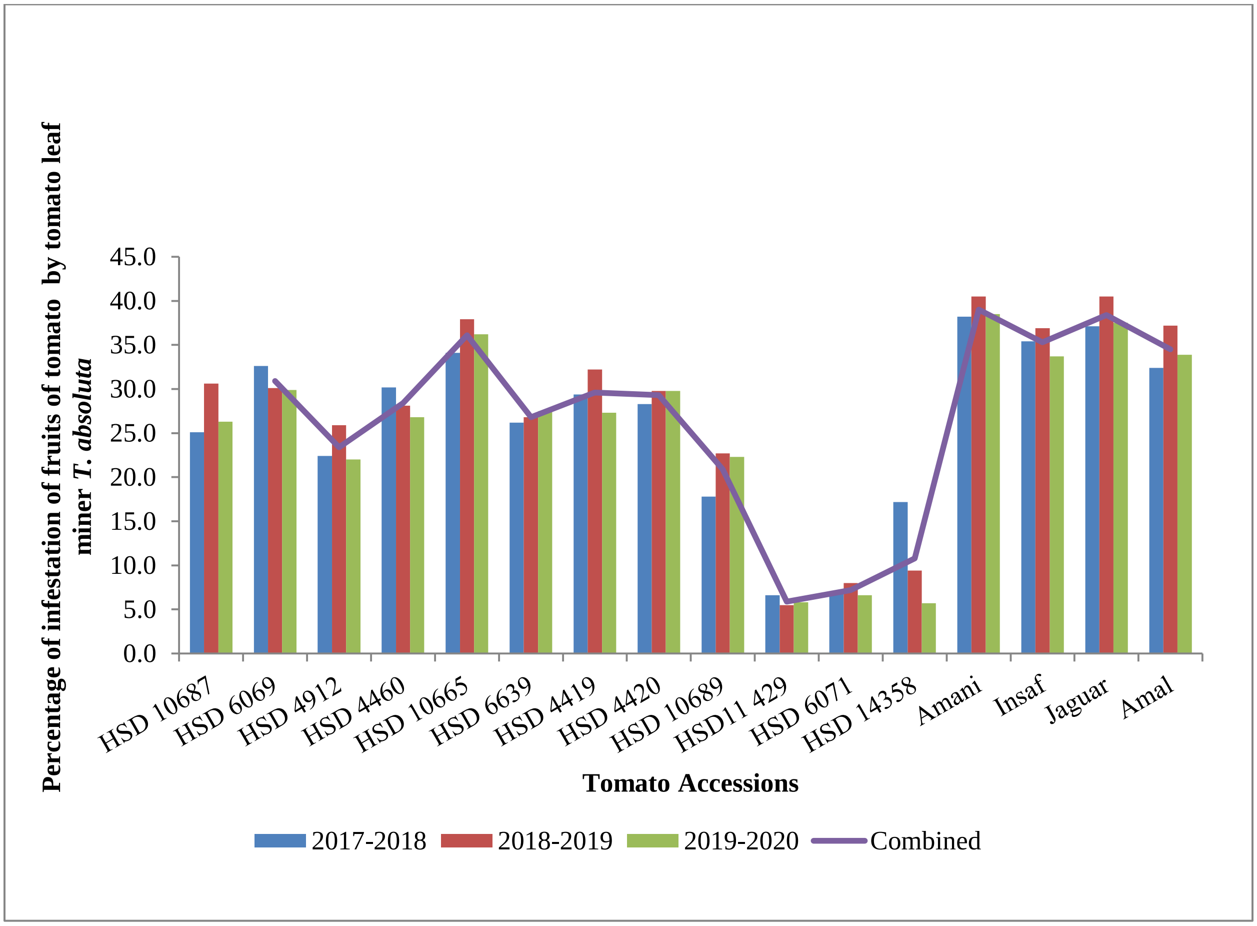

Figure (4): Mean percentage of tomato fruits infested by tomato leaf miner *T.absoluta on* tomato accessions for three consecutive seasons and their combined analysis

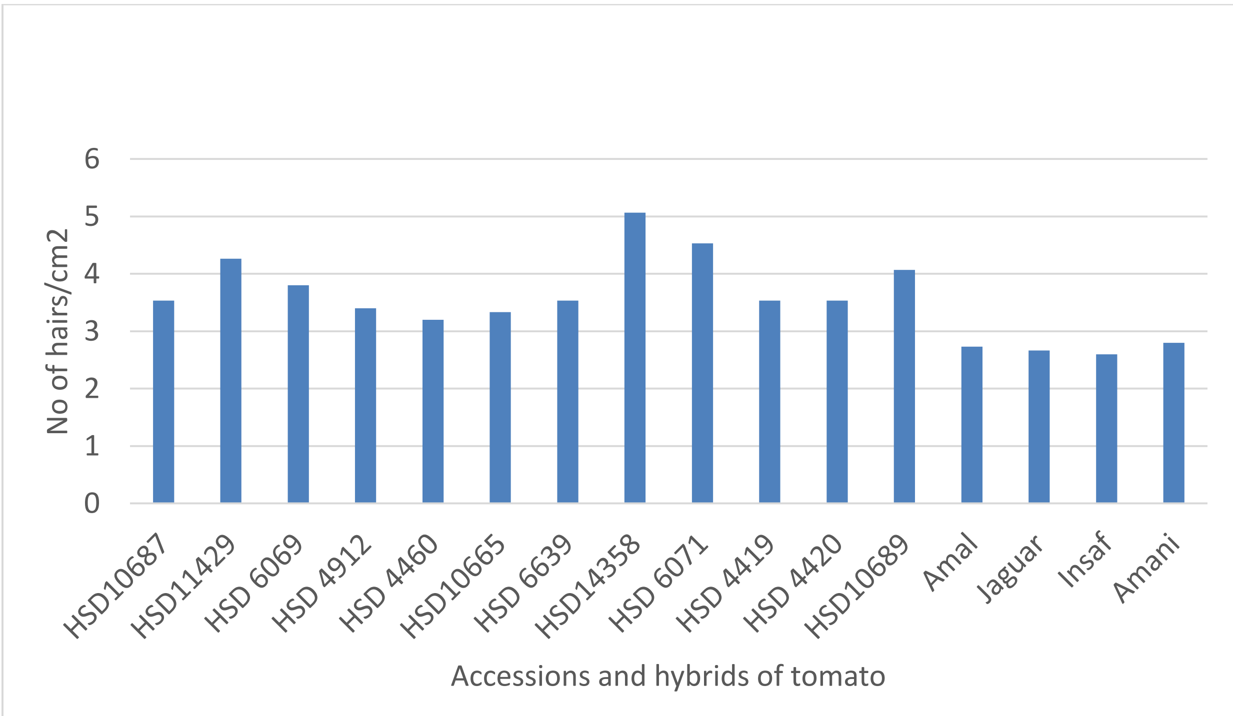

Figure (5): Number of hairs/ cm2 of leaves of accessions and hybrids of tomato evaluated against *T.absoluta*, Kassala, Sudan

4.1.6. Fruit Diameter

Table 11 and Figure 6 represent high significant difference among fruit diameter of tomato accessions and hybrids evaluated against *T. absoluta* for the three consecutive seasons. The combined analysis for the three seasons showed high significance on fruit diameter between accessions and seasons while no significant difference was observed on the interaction between seasons and accession and hybrids. The result showed that fruit diameter of all tested accessions is shorter than that of hybrids. The fruit diameter of hybrids ranged between (4.8-5.2) while that of accessions ranged between (2.6-4.5).

Table (11): Fruit diameter of some tomato accessions evaluated against leaf miner *T.absoluta* in Kassala State, Sudan for three consecutive seasons and their combined analysis.

Accession	Fruit Diameter			Combined
	2017-2018	2018-2019	2019-2020	
HSD 10687	2.7 C	2.9 D C	3.0 B	2.9 DC
HSD 6069	2.8 C	3.0 C	2.9 B	2.9 DC
HSD 4912	2.6 C	2.6 D C	2.9 B	2.7 DC
HSD 4460	2.4 C	2.6 D C	2.6 B	2.6 D
HSD 10665	2.8 C	3.1 C	3.0 B	2.9 C
HSD 6639	2.9 C	2.7 DC	3.1 B	2.9 DC
HSD 4419	2.6 C	2.5 DC	2.7 B	2.6 D
HSD 4420	2.5 C	2.4 D	2.8 B	2.6 D
HSD 10689	2.3 C	2.9 DC	3.2 B	2.8 DC
HSD11 429	4.1 B	4.5 B	4.8 A	4.5 B
HSD 6071	2.7 C	3.0 C	2.9 B	2.9 DC
HSD 14358	2.8 C	2.9 DC	2.9 B	2.9 DC
Amani	5.0 A	5.0 DA	5.2 A	5.1 A
Insaf	5.0 A	4.8 BA	5.1 A	4.9 A
Jaguar	4.9 A	5.1 BA	5.2 A	5.0 A
Amal	5.0 A	5.2 A	5.2 A	5.1 A
DF				
C.V	6.3	5.9	5.6	5.9
Pr> F Accession	<.0001	<.0001	<.0001	<.0001
Pr> F Seasons				<.0001
Pr> F Accessions*Seasons				0.1
Std Error	0.2	0.1	0.2	0.1

Means followed by the same latter (s) were not significantly different at (P≤0.05). .

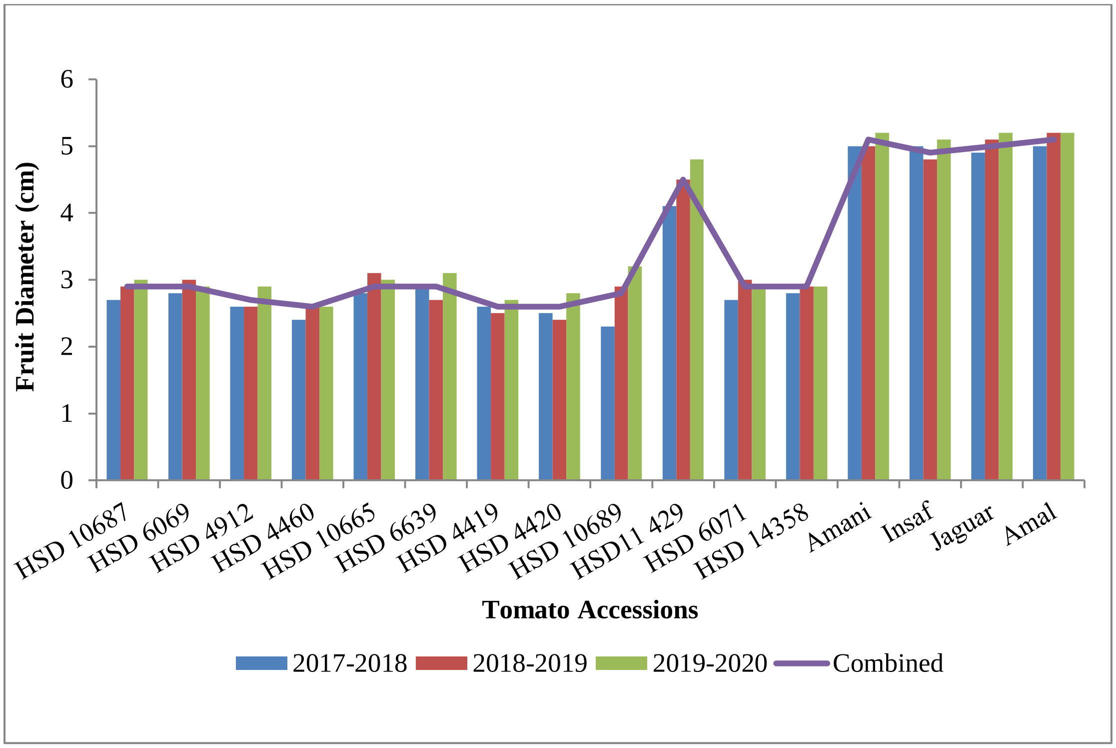

Figure (6): Fruit diameter of some tomato accessions evaluated against leaf miner *T.absoluta* in Kassala State, Sudan for three consecutive Seasons and their combined analysis

4.1.7. Total Soluble Solid (TSS)

High significant differences was observed between accessions and hybrid (Pr> F <.0001) and also between seasons (Pr> F <.0001) on the quantity of TSS for the three seasons. The combined analysis showed no significant difference between the interaction of seasons and accessions. Accessions HSD6071, HSD14358 and HSD11429 gaved the highest content of TSS mean (4.8) followed by other accessions which their content ranged between (3.3 to 3.9) while the hybrids statistically are same in their content of TSS (2.9-3.1) (Table 12 and Figure 7). TSS was found correlated highly negative with the percentage of infested leaves/plot (-0.82977, <.0001), number of mines/plot (-0.84764, <.0001) and percentage of infested fruits (-0.81465, <.0001) while it correlated highly positive with (0.64773, <.0001).

Table (12): Total Soluble Solids (TSS) of some tomato accessions evaluated against infestation by Tomato leaf miner *T. absoluta* in Kassala State, Sudan for three consecutive Seasons and their combined analysis

Accessions	TSS			Combined
	2017-2018	**2018-2019**	**2019-2020**	
HSD 10687	3.2 DC	3.8 B	4.0 DC	3.7 CD
HSD 6069	3.1 DC	3.6 C BD	3.8 DFCE	3.5 CD
HSD 4912	3.0 D	3.7 CB	3.8 DFCE	3.5 CD
HSD 4460	3.1 DC	3.3 FCEBD	3.4 DFE	3.3 GFDE
HSD 10665	3.2 DC	3.7 CBD	3.6 DFCE	3.5 CD
HSD 6639	3.2 DC	3.5 CEBD	3.5 DFCE	3.4 CFDE
HSD 4419	2.7 D	3.8 CB	3.8 DCE	3.5 CDE
HSD 4420	2.9 D	3.2 FCED	3.7 D FCE	3.3 GFDE
HSD 10689	3.7 DC	3.8 CB	4.1 BC	3.9 B
HSD11 429	4.3 BC	4.7 A	4.8 BA	4.6 A
HSD 6071	4.7 A	4.8 A	4.9 A	4.8 A
HSD 14358	4.3 BA	4.7 A	4.7 BA	4.6 A
Amani	2.8 D	2.9 F	3.4 DFCE	3.0 GF
Insaf	2.9 D	3.1 FED	3.3 DFE	3.1 GFE
Jaguar	2.9 D	2.9 E	3.1 F	2.9 G
Amal	2.7 D	2.9 FE	3.1 F	2.9 G
DF				
C.V	6.7	5.2	6.1	
Pr> F Accessions	<.0001	<.0001	<.0001	<.0001
Pr> F seasons				<.0001
Pr> F Accessions*seasons				0.01
Std Error	0.09	0.1	0.1	0.1

Means followed by the same latter (s) were not significantly different at (P≤0.05). .

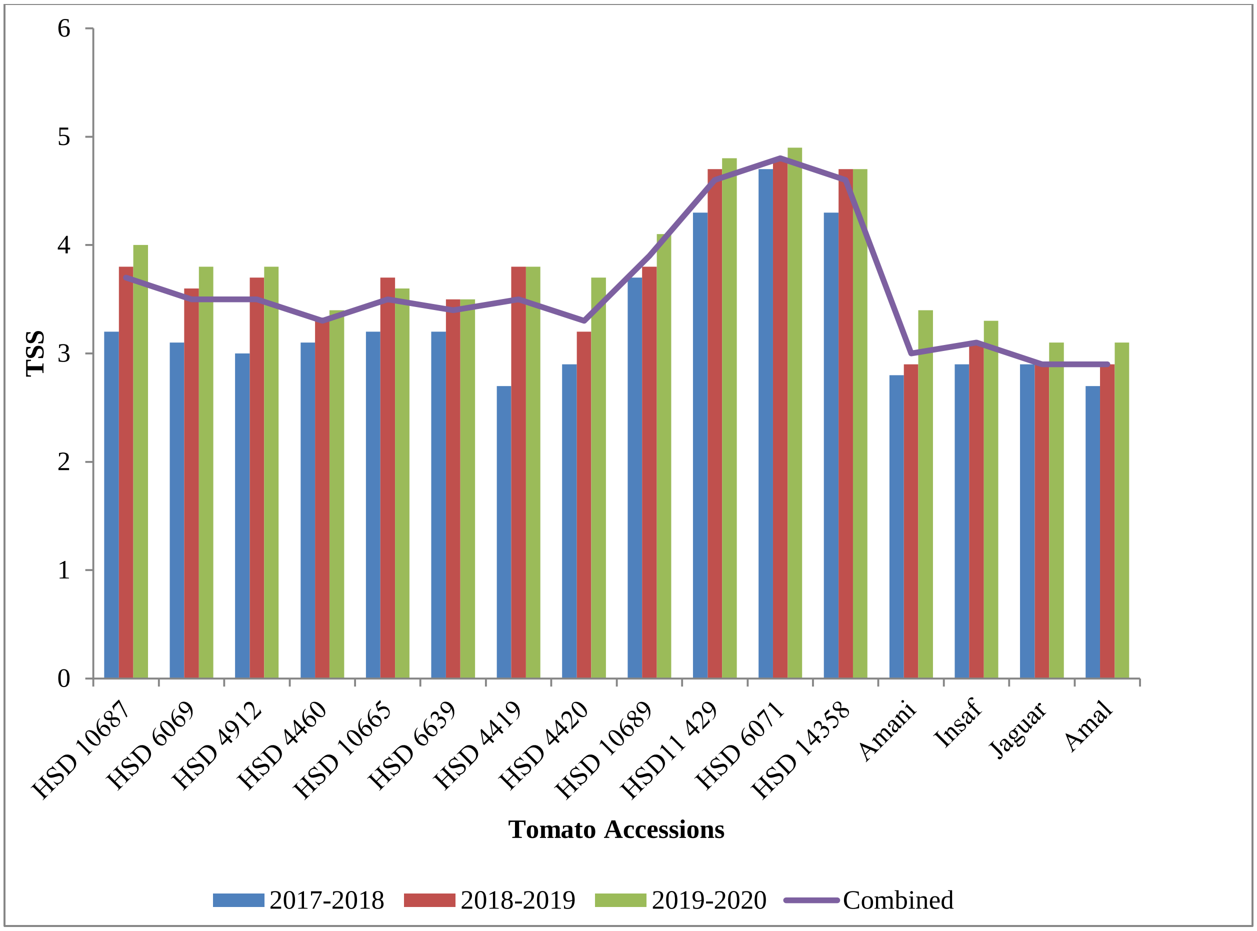

Figure (7): Total Solube Solid (TSS) of some tomato accessions evaluated against infestation by tomato leaf miner *Tuta absoluta* in kassala state, Sudan for three consecutive Seasons and their combined analysis

4.1.8. Chemical constituents

4.1.8.1. Lycopene (mg/kg dry wt.)

Significantly, lycopene is highly different (Pr > F <.0001) for all tested accessions and hybrids of tomato. Accession HSD4420 obtained the highest content of lycopene(22.7) while the hybrid Insaf recorded the least content (15.2) (Figure 8).Negative weak correlation was observed between the content of lycopene and percentage of infested plants, number of active mines, percentage of infested fruits as well as yield.

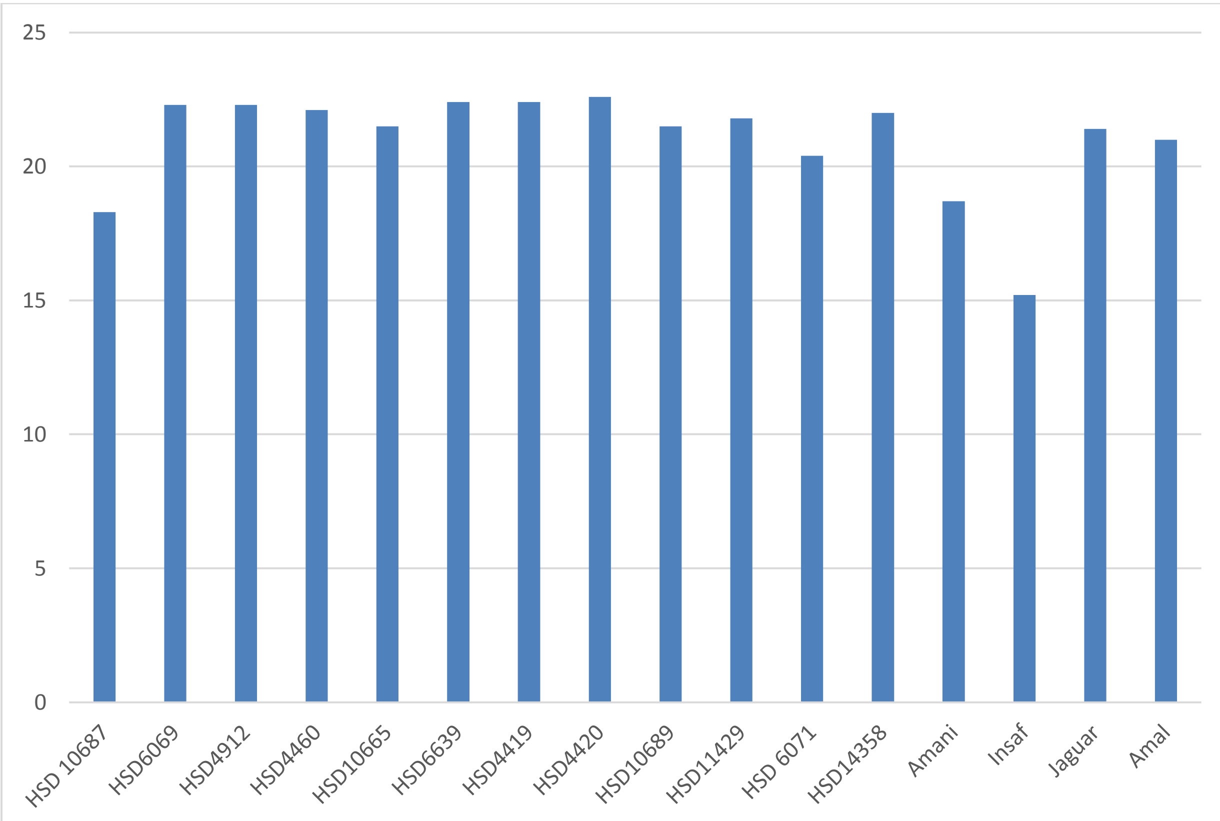

Figure (8): Lycopene constituents in tomato accessions evaluated against *Tuta absoluta.*

4.1.8.2. Tannin as mg Catechin Equivalents

High significant difference was noted between accessions and hybrids on the content of Tannin ranged between (1.6-12.6). HSD 14358 obtained the highest Tannin content followed by HSD11429 while HSD10665 recorded the least content (Figure 9, plate.11).

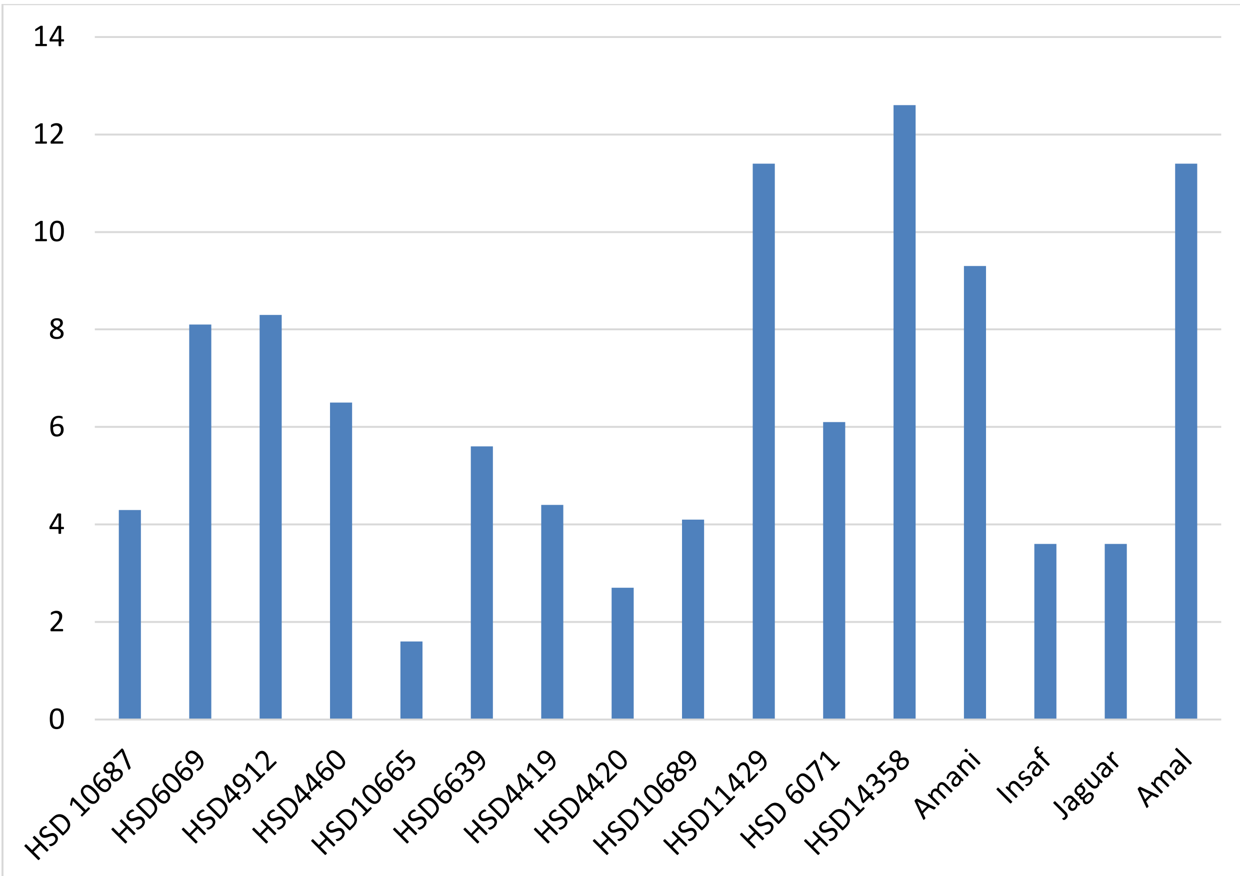

Figure (9): Tannin constituents in tomato accessions evaluated against *Tuta absoluta*

Plate No.11: High tannin (HSD 14358) .

Moderate negative correlation (-0.5409) was observed between the content of accessions of Tannin and percentage of infested plants/plot while weak negative correlation with number of active mines and percentage of infested fruits and a weak positive correlation with yield.

4.1.8.3. Carotene (μg β-- carotene /g)

Figure 10 showed significant difference among accessions and hybrids on the content of carotene which ranged between 45.4 for accession HSD6069 and 26.4 for hybrid Insaf. Weak positive correlation was recorded between Carotene and number of infested plants, number of active mines, percentage of infested fruits while weak negative correlation was noticed for carotene with yield.

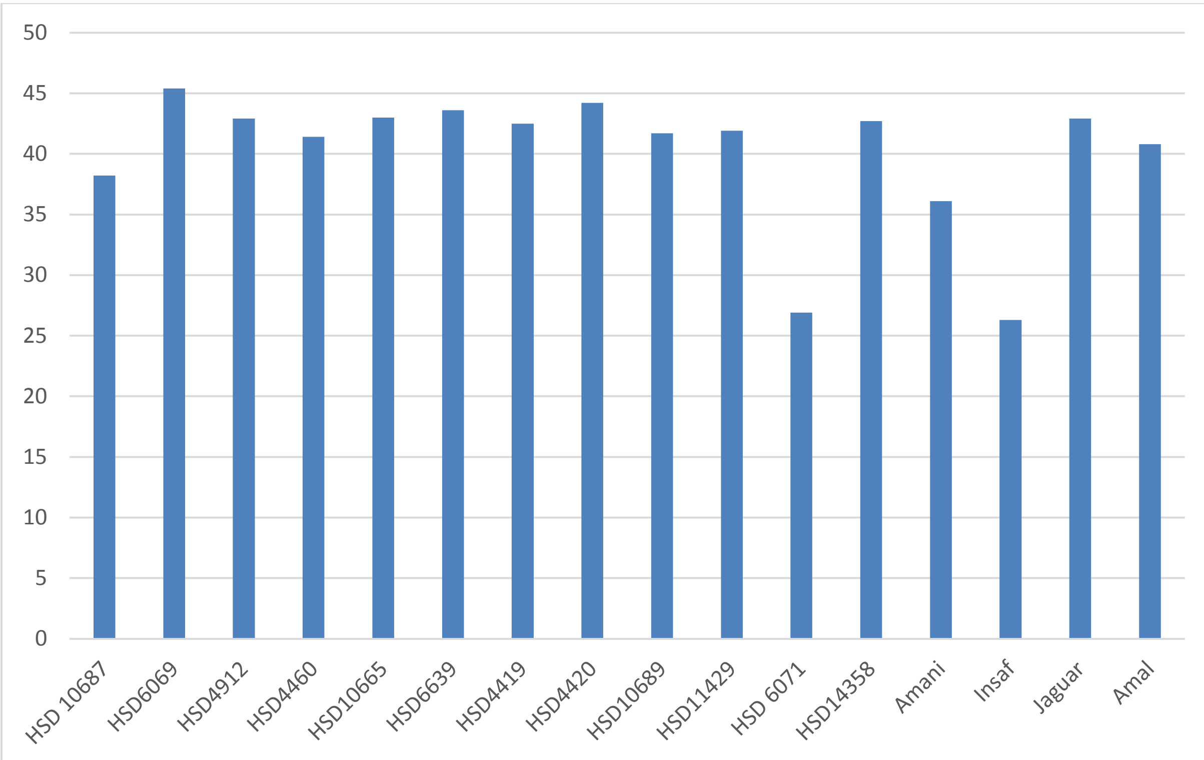

Figure (10): Carotene constituents in tomato accessions evaluated against *Tuta absoluta*

4.1.8.4. Ascorbic acid mg /100 g dry weight

Significant difference was observed between tomato accessions and hybrids on the content of Ascorbic acid or vitamin C (Pr > F <.0001) the content of Ascorbic acid ranged between (18.4 to 28.2). HSD 4419 obtained the highest content of vitamin C (Figure 11, plate.12). Very weak negative correlation was obtained between the content of vitamin c and the percentage of infested plant, number of live mines, percentage of infested fruits while positive weak correlation was recorded for the trait with the yield.

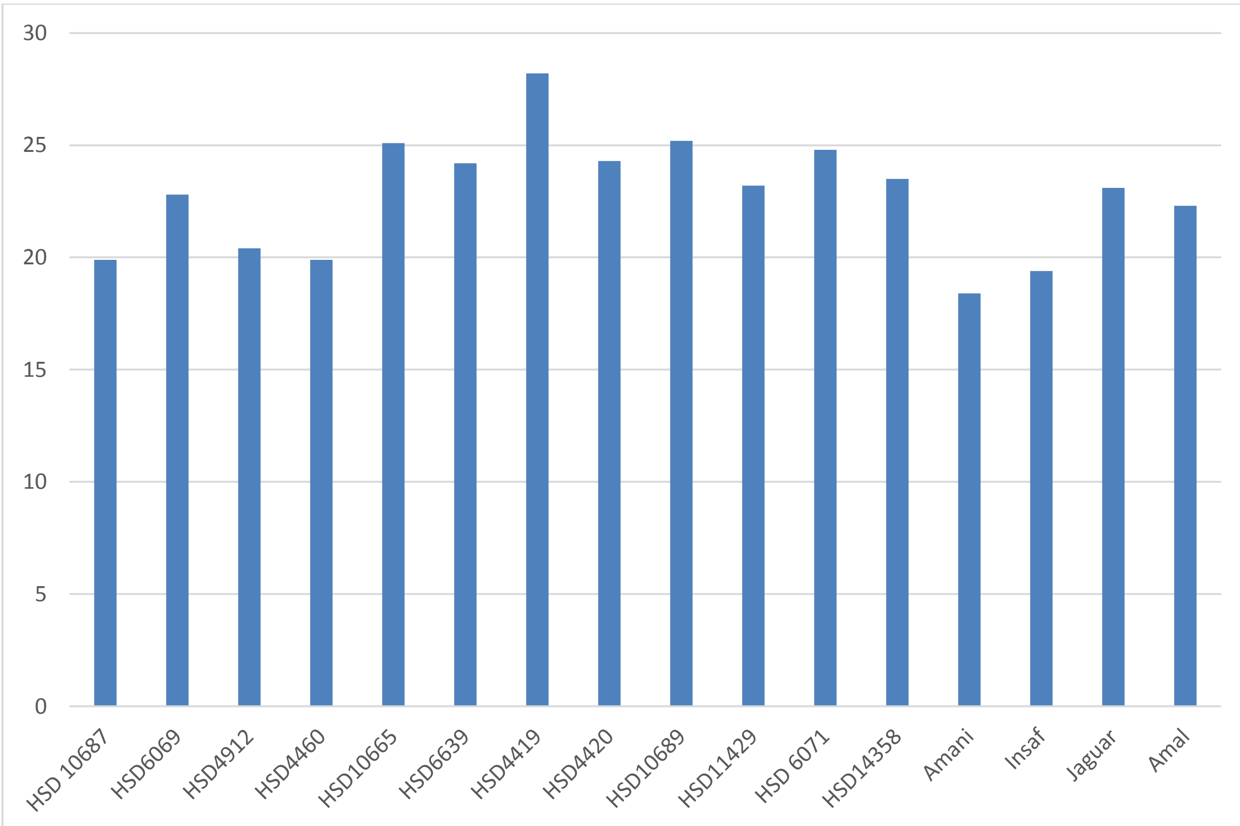

Figure (11): Ascorbic Acid constituents in tomato accessions evaluated against *Tuta absoluta*

Plate No.12: High Ascorbic Acid(HSD 4419) .

4.1.9. Yield of accessions and hybrids of tomato evaluated against infestation caused by tomato leaf miner *T. absoluta*.

Table. 13, showed high significant difference on tomato yield (Tons/hectare) between the accessions and hybrids for the three seasons. Also, the high significant difference was appeared on the combined analysis between accessions and hybrids (pr> f< 0001), among seasons (pr> f <0001) as well as among the interaction between accessions and hybrids and seasons (pr> f<0001). The accession HSD 6071, recorded the highest yield for the three seasons (7.9 Ton/Ha) followed by HSD 11429, HSD 14385, HSD 10689, HSD 10687 with 7.3, 6.7, 5.7 and 5.6 respectively. Same yield was obtained for the local checks (hybrids) ca 5.3 (Ton/Ha). The rest of the remained accessions obtained between 3.4 to 5 ton/ha (Table 13, Figure 13 and plate.13). The yield was correlated positively with TSS (0.64773, <.0001) and correlated highly negative with number of infested plants (-0.76520, <.0001), number of life mines (-0.74567, <.0001) and moderately positive with percentage of infested fruits (0.58991, <.0001).

Table (13): Yields of accessions of tomato evaluated against infestation by Tomato leaf miner in Kassala State, Sudan for three consecutive seasons and their combined analysis

Accessions	**Yield Ton/Ha**			**Combined Ton/Ha**
	2017-2018	**2018-2019**	**2019-2020**	
HSD 10687	4.9 DE	5.5 EF	6.3 BDC	5.6 D C
HSD 6069	3.0 G	3.5 J	3.8 G	3.5 E
HSD 4912	3.2 FG	3.7 J	3.9 FGE	3.6 E
HSD 4460	3.4 FG	3.6 J	3.9 FGE	3.6 E
HSD 10665	3.1 G	3.4 J	3.7 G	3.4 E
HSD 6639	3.5 FG	4.2 I	4.5 FGDE	4.1 E
HSD 4419	3.3 FG	3.8 JI	4.9 FGED	4.0 E
HSD 4420	4.2 FE	4.7 H	6.2 BDC	5.0 D
HSD 10689	5.2 D	6.0 D	6.0 BDC	5.7 C
HSD11 429	6.2 BC	6.8 C	7.1 BA	6.7 B
HSD 6071	7.3 A	8.1 A	8.4 A	7.9 A
HSD 14358	6.3 BA	7.6 B	7.6 BA	7.3 B A
Amani	4.9 DE	5.2 GF	5.8 FBEDC	5.3 D C
Insaf	4.8 DE	5.2 GF	5.9 BEDC	5.3 D C
Jaguar	5.0 DE	5.6 ED	4.8 FGED	5.2 D C
Amal	5.0 C	4.9 GH	5.3 FGEDC	5.2 D C
C.V	6.9	2.8	11.7	8.3
Pr> F	<.0001	<.0001	<.0001	<.0001
Std Error	0.19	0.2	0.2	<.0001
Pr> F Seasons				<.0001
Pr> F Season*Varieties				0.02

Means followed by the same latter (s) were not significantly different at (P≤0.05). .

Plate No.13: High yield (HSD 6071) .

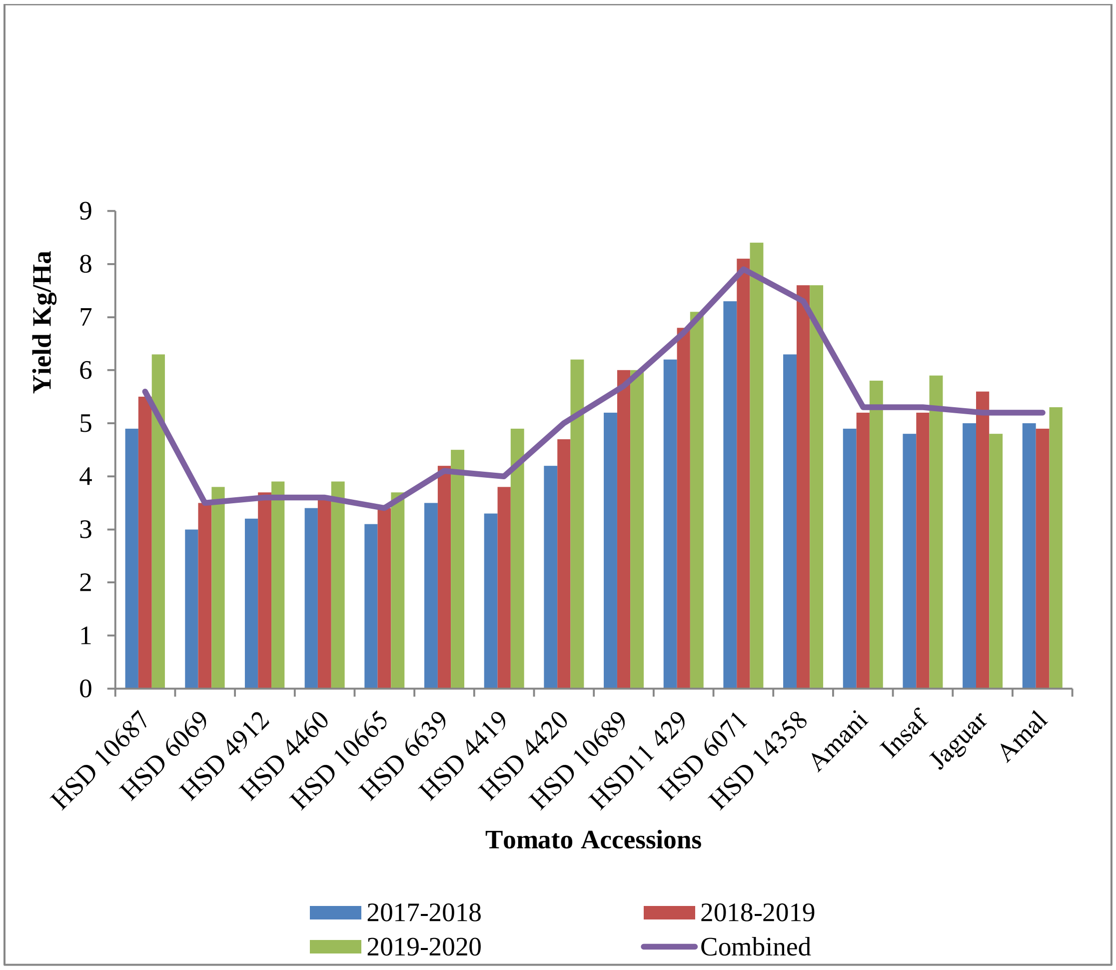

Figure (12): Yield of accessions of tomato evaluated against infestation by Tomato leaf miner in kassala State, Sudan for three consecutive Seasons and their combined analysis.

4.2. Effect of oil of Neem seed (*Azadirachta indica A. Juss*) and aqueous extracts of Jimsonweed (*Datura stramonium L)* and Periwinkle*(Vinca rosea L.) on T. absoluta*

4.2.1. Effect of test products on the mean percent of infested plants/plot

Table 14 showed the effect of test products on the mean percent of infested plants/plot for the three sprays:

4.2.1. 1. First spray

Mean percent of tomato plants infested by *T. absoluta* was significantly different between treatments after 48 hours, all test products were better than the control. Same results of reduction on number of infested plants was recorded for Neem seed oil, Water extract of Datura as well as Dancid® the chemical insecticides followed by water extract of Vinca. High significant difference was observed after 72 hours post spray in spite of increase of number of infested plants but the result was same for the four treatments including water extract of Vinca with average of 37.1 infested plants while the control reached 57.5 infested plants. After 7 days number of infested plants was increased significantly compared to 48h and 72h. Untreated plots obtained highest number of infested plants (67.2plants/plot) while Plots treated with water extract of Datura generally were less infested followed by same effects on plots treated with Neem seed oil and Dancid®(the insecticide).

4.2.1. 2. Second Spray

As demonstrated in Table 14. High significant difference was observed between the number of infested plants/plot after 48h and 72h of the second spray. All test products reduced the number of infested plants/plot less than the control plots. Neem seed oil and WE of Datura were better fluctuated between (18.4-22.5) infested plants/plot in reducing the number of infested plants/plot than WE of Vinca and Dancid®(the insecticide). As in the first spray the number of infested plants was slightly increased in treated plots after 7 days (26-33plants/plot) when compared to very high number (75.4) of infested plants/plot recorded for the control. High significant difference was observed between the treatments. Effect of WE of Datura in infested plants/plot was comparable to that of Danicd® followed by Neem seed oil and WE of Vinca.

4.2.1. 3. Third Spray

In table (14) All test products reduced the number of infested plants/plot with high significant difference between treatments in 48h, 72h and 7days post spray count. Water extract of Datura was the best product that reduced the number of infested plants/plot followed by Neem seed oil then Dancid® and Vinca. After 7 days of the third spray, all test products were same in their effects and significantly reduced the number of infested plants/plot to (18-22) which were better than (82.1)infested plants/plot in the control plots.

Table 14: Effect of water extracts of Wenca, water extract Datura, Neem seed oil and Dancid® on mean percent of plants infested by *T. absoluta*/plot on tomato plants

Treatment	Pre-spray	1st Post-spray			2nd Post-spray			3rd Post-spray		
		48hrs	72hrs	7days	48hrs	72hrs	7days	48hrs	72hrs	7days
Dancid®	40.9	32.7b	36.4b	38.2cb	29.0b	30.0b	26.0c	22.1cb	20.6b	18.4b
WE of Vinca	44.3	40.2 ba	37.1b	43.9b	31.9b	26.5cb	33.4b	25.8b	20.5b	22.0b
WE of Datura	40.5	29.5b	31.9b	36.03c	18.4c	20.8c	26.4c	14.4d	14.4c	19.2b
Neem seed oil	41.7	32.9b	33.5b	41.3cb	21.8c	22.5c	28.8cb	17.1cb	17.3cb	19.5b
Control	44.0	49.2a	57.5a	67.2a	53.7a	67.9a	75.4a	59.0a	71.0a	82.1a
C.V	11.0	16.2	7.6	7.0	11.8	10.6	7.3	14.0	10.5	9.0
SE±	1.12	2.23	2.66	3.1	3.4	4.7	5.1	4.4	5.8	6.7
Pr ≥F	0.6603	0.0228	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

WE= Water extract. Data with same letter are significantly equal

4.2.2. Effect of different test products on active mine of *T. absoluta*:

The effect of three sprays of different test products on number active mines of *T. absoluta* was presented in Table15.

4.2.2. 1. First Spry

In the first count significant difference was observed between treatments for pre spray count as well as for 48h, 72h and 7 days post spray. After 48 h of spray, WE of Datura gave better reduction in active mines (16.7) caused by larvae of *T. absoluta* followed by Dancid, Neem seed oil and WE of Vinca with 19,21, 24.7mines while the control recorded (28.3) mines (Table 15). After 72 h Neem seed oil, Dancid® and WE of Datura showed similar effect on the active mines which were less than the control. The number of mines 7 days' post spray was significantly same for all test products which were less than the control.

4.2.2. 2. Second Spray

In the second spray it was noticed that the number of mines decreased than its situation after 7 days in the first count. Significant differences were observed between treatments on the number of mines for 48h, 72h and 7days post spray. In all post spray counts, Plots treated with WE extract of Datura gave the lowest number of mines (mean=12.7) followed by Dancid® (mean=12.7), Neem seed oil (mean=15.3) and Vinca (mean=17.7) while the control recorded (mean= 36.3) mines.

4.2.2. 3. Third Spray

High significant difference was observed between treatments on the number of mines for 48h, 72h and 7days of the 3rd post spray counts (Pr $\geq$F 0.0001). The number of mines decreased gradually and successively according to time elapse for all tested products while vice versa was reported for the control. Table 15 demonstrated same reduction effect of number of mines due to use of WE of Datura, Dancid® and Neem seed oil followed by WE of Vinca for the three post spray counts.

Table 15: Effect of water extracts of Wenca, water extract Datura, Neem seed oil and Dancid®on mean number of active mines of *T. absoluta*/plot on tomato plants.

Treatment	Pre-spray	1st Post-spray			2nd Post-spray			3rd Post-spray		
		48hrs	72hrs	7days	48hrs	72hrs	7days	48hrs	72hrs	7days
Dancid®	24.0b	19dc	17.7c	19.0b	13.7dc	12.7c	12.7c	8.7c	8.0c	7.7c
WE of Vinca	28.8a	24.7b	25.3b	22.3b	21.3b	19.7b	17.7b	16.3b	13.7b	11.7b
WE of Datura	23.7b	16.7d	18.7c	20.3b	11.7d	12.7c	13.3cb	8.0c	8.0c	6.7c
Neem seed oil	28.2a	21.0c	20.3c	21.3b	16.0c	15.3cb	16.0cb	10.3c	9.7c	7.3c
Control	27.1a	28.3a	32.3a	36.2a	31.3a	36.3a	39.3a	34.3a	38.7a	45.3a
C.V	5.4	8.3	7.3	9.1	10.3	13.3	11.6	7.8	13.5	11.1
SE±	0.6	1.2	1.5	1.8	1.9	2.4	2.7	2.6	3.2	4.0
Pr ≥F	0.0123	0.0004	<.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

WE= Water extract. Data with same letter are significantly equal

4.2.3. Effect of test products on the percentage of tomato fruits infested by *T. absoluta*

Results displayed in Table (16) revealed that there was significant difference between treatments on the percentage of fruit damage. Statistically equal reduction to the percentage of damaged fruits was recorded for WE of Winca, Neem seed oil, Dancid, WE of Datura ranged between (26.8 - 31.0%) while the control recorded the highest fruit damage percentage (49.4%) according to the infestation by *T. absoluta.*

4.2.4. Effect of different test products used to control *T. absoluta* on yield of tomato:

The obtained results of yield of tomato (Tons/hectare) due to the use of some products to control *T. absoluta* revealed high significant difference (Pr≥F 0<.0001) between all test products and control. All test product improved yield 2 to 3 times better than the control. Neem seed oil obtained the highest yield (11.2 Ton/ha) among all test products followed by WE of Datura (9.9), Danicd® (9.7), WE of Vinca (8.8 Tons/ha) while the least yield (3.8 Tons/ha) was recorded to the control (Table.17).

Table 16: Effect of water extract of Vinca, water extract of Datura, Neem seed oil and Dancid® on (%) of fruits damaged by *T. absoluta*

Treatment	**Fruits Damage (%)**
Dancid®	28.03b
WE Vinca	26.8b
WE Datura	31.0b
Neem seed oil	27.1b
Control	49.4a
C.V	27.2
SE±	3.0
Pr≥F	0.0595

WE= Water extract. Data with same letter are significantly equal

Table 17: Effect of application of water extracts of Vinca, water extract of Datura, Neem seed oil and Dancid® to control *T. absoluta* on tomato yield (Tons/ha)

Treatment	**Yield (Tons/hectare)**
Dancid®	9.7b
WE Vinca	8.8c
WE Datura	9.9b
Neem seed oil	11.2a
Control	3.8d
C.V	4.2
SE±	0.6
Pr≥F	0<.0001

WE= Water extract. Data with same letter are significantly equal.

CHAPTER FIVE

DISCUSSION

The defense mechanisms of plants to the attack of herbivores are highly diverse and wide ranging. Plants interact to the attack of herbivores through different morphological, biochemical and molecular mechanisms. The morphological traits include thickness of cell wall, wax of leaf surface, trichomes or thornes, and lignifications; these traits form the first physical barrier to feeding, egg laying and development of premature stages of herbivores. Biochemical defense of plants is direct or indirect, the direct effect is through reproduction and emission of some lethal or repellent materials that prohibit herbivores to feed or lay eggs or use the plant even as shelter, while indirectly plants release some volatile organic compounds that attract natural enemies, and sometimes these biochemical are produced in response to plant damage, and affect feeding, growth, and survival of herbivores. In this current study, the 12 Sudanese tomato accessions that were evaluated in the filed against the infestation of *T. absoluta* revealed significant difference among the accessions on their susceptibility, tolerance or resistance to the infestation of the pest.

Very low infestation parameters were recorded for three accessions (i.e., HSD11429,HSD14358andHSD6071)for the percentage of infested plants/plot, number of active mines/ plant and percentage of infestation of fruits while the same three accessions recorded the highest yield compared to other accessions and hybrids (the control (Local Checks). The results of reduction of infestation of *T. absoluta* due to specific genotypes was mentioned by Mohamed *et al*, (2020) who reported that genotypes Salama and RILG3- 162 were very low infested genotypes among others in Sudan.

Also, the same results were obtained by genotypes TOM-688 and TOM-68 (Maluf*et al*., (2010). Less infestation percentage by tomato leaf miner was observed in genotypes IIVR Sel-1, JKTH-3064 and Mani khamenu (Naik *etal*., 2005). The most tangible advantage in the current study in addition to the resistance performance of the three elite accessions to the infestation by *T. absoluta* is their superiority in the yield. This finding is not in agree and refuted the general theorythat assumed hybrids as superior to open-pollinated varieties for earliness, yield, resistance attributes and better adaptability than open-pollinated varieties which raised by (Kalloo, 1993).

5.1Trichomes:

The accessions showed significant differences on the density of trichomes, the highest number of trichomes was reported for the three elite accessions. These trichomes or hairs are anatomical feature on leaves, wide-ranging in forms and functions within species and genotypes. In this study, the three elite accessions obtained the highest density of the trichomes although the highly negative correlation of trichomes with the percentage of infested plant, number of mines/plant and percentage of infested fruits is in agree with several studies confirmed that the dense of trichomes reduces the chances for insects to feed, lay eggs and develop on specific plants. Peter *et al*., (1995). considered this phenomenon as indicator of resistance.Khederi *et al*., (2014) reported that Trichome type and density of tomato genotypes correlated negatively to the population density of *T. absoluta*. The mechanism of Trichomes to act as an insect resistance depend on a theory consisted of three roles: 1) a physical barrier that limits contact of insect's to the plant tissue, 2) by producing toxic compounds which poison the insect through contact, ingestion and/or inhalation and 3) by producing gummy, sticky or polymerizing chemical exudates which hindered the insect (David and Easwaramoorthy, 1988; Duffey, 1986). Riquelme, (2009) recorded that, females of *T. absoluta* tended to concentrate their egg laying activity on the upper third of the tomato plants on the leaves (both sides). Trichomes, reduce the access of insects to leaf epidermis with different shapes, these can be, straight, spiral, hooked, branched, or unbranched and can be glandular or non-glandular. The Glandular trichomes secrete secondary metabolites forming a combination of structural and chemical defense including flavonoids, terpenoids, and alkaloids which are poisonous, repellent, or trap insects and other organisms (Karabourniotis *etal*., 2020). Selvanarayanan and Muthukumaran, (2005) reported that, the density of three types of non-glandular and two types of glandular trichomes and phenol content in the foliage were exerted by hybrids lesser feeding and ovipositional preference and higher antibiotic effects on different insect stages.

5.2 Total Soluble Solid

Part of the results of present study, revealed the significant increase of Total Soluble Solids in the three elite accessions and also reported its high negative correlation with the percentage of infested leaves/plot number of mines/plot and percentage of infested fruits. The obtained results of TSS for the tested accessions are in accordance with findings of Vijeth *et al*., (2018), who stated that, hybrids of tomato showed resistance to the leaf curl disease due to the increase of TSS content. On other study (Maldonado *etal*., 2008) noted that resistance of spore increases with higher TSS.

5.3 Chemical analysis

Chemical analysis of fruits of tomato accessions for lycopene, Ascorbic acid, tannin and carotene showed significant difference between accessions on the content of the four chemical compounds. Selvanarayanan and

Muthukumaran, (2005) reported that, the lycopene and Ascorbic acid content in the fruits of Hybrid 3 (Ac 238 x Roma) were the major factors of resistance to *H. armigera*, leaf caterpillar, *Spodoptera litura* Fab. Noctuidae: Lepidoptera), leaf miner, *Liriomyza trifolii* Blanchard (Agromyzidae: Diptera) and whitefly, *Bemisiatabaci* Genn. (Aleyrodidae: Hemiptera). All chemicals in this study were found correlated very weak negatively with percentage of infested plant, number of active mines and percentage of infested fruits except Tannin which correlated moderately negative of percentage of infested plants/plot. Studies carried out (Kubo, 2006) confirmed that tannins inhibit *Pectinophora gossypiella* larvae when ingested in small amounts and also it works as defense mechanism against herbivore.

5.4 Botanicals

In the last seven decades many botanical formulations have proven to be potent and effective as many as conventional synthetic pesticides even at low concentrations. In fact, botanical insecticides have drawn great attention as major control agents in organic farming. However, their extensive uses have resulted in certain drawbacks and hazards, including, persistence, toxicity to non- target organism, pest resistance and environmental pollution (Siquira *etal.,* 2000; Lietti *et al*., 2005). Many studies have been focused on the use of botanical extracts includes oil, powder, ethanolic or aqueous extract for their effectiveness, cheapness, short persistence and low mammalian toxicity. Stoll, (2000) and Hiiesaar *et al*., (2001) reported that, many of plant materials show abroad spectrum of activities against insect pests including lethal, anti-feedant, repellent and growth regulatory effects. Azadirachtin is awell known effective botanical insecticide extracted from Neem plant (Mordue and Alasdair, 2000). The tomato leaf miner, *T.absoluta*, anew pest in Sudan, has caused excessive damage to tomato in all parts of country since 2010 (Mahmoud *et al*., 2020). In this study, the aqueous extracts of Datura and Vinca and Neem seed oil were applied to tomato plots infested by *T. absoluta* to determine their effect on number of infested plants/plot, active mines/plot and fruit damage/plot as well as their effect on yield of the crop. The results revealed significant difference among the test plant extracts compared to the standard and control for three consecutive sprays for the above mentioned parameters. The results of using neem oil are in agreement with findings of (Coelhoand Deschamps, 2014) who stated that, the insecticidal and anti-feedant effect of neem on caterpillars of *T. absoluta*. Also the results of using neem oil is in accordance with (Illakwahhi and Srivastava2019) who reported the potency of using neem oil as insecticide and as synergist to increase activity of abamectin to control *T. absoluta* and reduce its resistance to abamectin. (Tindade *et al*. 2000), reported that 84-100% control was achieved using different concentrations of Neem seed extract against young larvae of *T. absoluta.* On other hand, results of the present study proved that, plots treated with neem seed oil gained the highest yield, the same results of increasing yield due to use of neem seed oil was mentioned by (Abbasi *et al*. 2003). Plots that were treated by WE of Datura were similar to Dancid® (the insecticide) extracted products which is better than findings of (Buragohain *et al*. 2021) who stated that neem extract reduced the infestation of *T. absoluta* similar to the standard insecticides without affecting the yield. In the current study, the effect of WE of Datura on reducing the number of infested plant/plot, number of active mines and percentage of infested fruits as well as increase yield was recorded which give the product the opportunity to be used as alternative to pesticides to control *T. absoluta* and increase yield of tomato crop. Habib *et al*.(2011). And Abbasipour *et al*., (2011) reported that the seed and leaves extracts of *D. stramonium* are effective to control *Tribolium castaneum* while Moreira *et al*. (2004) reported that, hexane and alcoholic extracts of *D. stramonium* had no insecticidal activity against larvae of *Diaphania hyalinata* (L.) (Lepidoptera: Pyralidae).

In spite of its effectiveness in controlling *T. absoluta*, Datura contains atropine, hyoscyamine, and scopolamine, which can produce poisoning with a severe anticholinergic syndrome which cause hallucinogenic and euphoric effects to human (Trancă *et al*. 2017). For the mentioned reasons further studies on residual effects of Datura is highly required. WE of Vinca is comparable to the insecticide (Dancid15%) in many post spray counts and comparable to other test products and much better than the control in the number of infested plant/plots and number of active mines and same as other test products on percentage of infested fruits. This results of Vinca is in agreement with results of mortality and repellency caused by its powder and aqueous extracts against Faba bean beetle, *Bruchidius incarnatus* (Boh.) under laboratory condition, (Mohammed 2004).

Conclusions and Recommendations

Conclusions

- Tomato fruit borer *T. absoluta* is amean of tomato crop worldwide causing heavy yield losses affecting the economics of young growers and industrial capacities of countries. Tremendous progress has been made in the development of potential germplasms in tomato for different purposes in Sudan. Screening of wild accessions of tomato for different traits are highly required in breeding programs, especially for insects and diseases resistance.
- Tomato breeding program is devoted to develop numerous varieties of tomato to produce suitable ones after selection system particularly pedigree, bulk, single seed descent and their modifications to be hybridized and used.
- Utilizing of the three elite accessions of tomato(i.e., HSD11429, HSD14358 and HSD6071) through increasing production of seeds and looking for possibilities of transfer of the resistance genes to commercial tomato cultivars is highly required to be incorporated in development of integrated management of tomato fruit borer.
- The use of Neem seed oil, WE of Datura and WE of Vinca as alternative to insecticides is effective to control *T. absoluta*. The extract of the three products reduced the number of infested plants/plot, number of active mines/plot as well as reducing the percentage of infested fruits and increased tomato yield.

Recommendations

- Based on the above mentioned results, tomato accessions HSD 14358, HSD 11429 and HSD 6071 are highly recommended to be used as sources of resistance against tomato fruit borer *T. absoluta* in Sudan.
- Also, farmers of tomato are advised to use Neem seed oil at (0.72 L/ha and use of WE of Datura and WE of Vinca at (0.96 L/ha) for the management of *T. absoluta*.
- Further studies for residual effect of WE of Datura and also preparation of formulations of the botanical extracts is required to encourage their application by farmers.
- Great efforts should be deployed in order to manage this pest using different control mechanisms such as insecticides, biocontrol agents, pheromone traps, field hygiene, light trapsand resistant varieties.
- The integration and incorporation of many control measures in addition to better understanding of the pest's life cycle and behavior will participate positively in reducing the damage of tomato fruit borer, safeguard human and environment as well as increasing tomato yield and alleviate poverty.

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APPENDICES

Appendix (1) : Number of days to 50% flowering by tomato leaf miner *T. absoluta* from different tomato accessions in Kassala State, Sudan season, (2017-2018/ 2018-2019/2019-2020)

Table(1)Season 2017 – 2018

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 26.5416667 13.2708333 __ __ 31.5777778 1.25 0.2911
473.666666715 Accession

Total 17 500.2083334

Season 2018 – 2019

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 13.5416667 6.7708333 __ __ 21.9097222 2.99 0.0052
328.645833315 Accession

Total 17 342.1875

Season 2019 – 2020

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 5.7916667 2.8958333 __ __ 8.3652778 1.65 0.1188
125.4791667 15 Accession

Total 17 131.2708334

Combine analysis:

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

---

seasons 511.51388892 255.7569444 20.97 <.0001

Rep 2 28.7638889---
21.6722222 1.78 325.0833333 15 Accession 0.0496
Accession*season 47 602.7083333 20.0902778 1.65 0.0364

Total 66 1468.0694444

Appendix 2: Mean percent of plants infested by tomato leaf miner *T. absoluta* from different tomato accessions in Kassala State, Sudan season, (2017-2018)

Table(2)1s**t count**

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 2.161667 1.080833 __ __ 329.925431 28.59 <.0001
4948.881458 15 Accessions

Total 17 4951.043125

2nd **count**

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 3.686667 3.686667 _ _

329.92543 64.39 <.00015524.313125 15 Accessions

Total 17 5527.999792

3rd **count**

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 2.501667 1.250833 _ _

505.697722 115.24<.00017585.465833 15 Accession

Total 17 7587.9675

4th **count**

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 2.461667 1.230833 _ _

658.418986 119.99<.00019876.284792 15 Accession

Total 17 9878.746459

5th **count**

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 5.97875 1.230833 _ _

946.12221 90.82 <.000114191.83313 15 Accession

Total 17 14197.81188

mutawsit

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 0.962917 0.481458 _ _

531.411500 122.35<.00017971.172500 15 Accession

Total 17 7972.135417

Appendix 3: Mean percent of plants infested by tomato leaf miner *T. absoluta* from different tomato accessions in Kassala State, Sudan season, (2018-2019)

Table(3)1st **count**

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 4.1450002.07250 __ __ 302.858208 55.79 <.0001
4542.87312515 Accession

Total 17 4547.018125
2nd **count**

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 37.15875018.579375 __ ___ 366.531556 80.40 <.0001
5497.97333315 Accession

Total 17 5535.132083

3th **count**

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 19.4512509.725625 __ __ 507.958542 69.76 <.0001
7619.37812515 Accession

Total 17 7638.829375

4th count

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob.
Rep	2	3.661667	1.830833	_	_
648.410167	76.05	<.00019726.152500	15	Accession	
Total	17	9729.814167			

5th count

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob.
Rep	2	148.29542	74.14771	_	_
895.01310	70.11	<.000113425.19646	15	Accession	
Total	17	13573.49188			

mutawsit

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob.
Rep	2	11.475417	5.737708	_	_
521.283500	155.74	<.00017819.252500	15	Accession	
Total	17	7830.727917			

Appendix 4: Mean percent of plants infested by tomato leaf miner *T. absoluta* from different tomato accessions in Kassala State, Sudan season, (2019-2020)

Table(4) 1st count

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob.
Rep	2	4.071667	2.035833	_	_
259.043056	25.84	<.00013885.645833	15	Accession	
Total	17	3889.7175			

2nd count

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob.
Rep	2	38.462917	19.231458	_	_
353.501764	55.31	<.00015302.526458	15	Accession	
Total	17	5340.989375			

3rd count

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob.
Rep	2	21.105417	10.552708	_	_
457.517986	84.68	<.00016862.769792	15	Accession	
Total	17	6883.875209			

4th count

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob.
Rep	2	24.391250	12.195625	_	_
599.492000	80.55	<.00018992.380000	15	Accession	
Total	17	9016.77125			

5th count

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob.
Rep	2	22.29292	11.14646	_	_
849.36261	53.80	<.000112740.43917	15	Accession	
Total	17	12762.73209			

mutawsit

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob.
Rep	2	9.645000	4.822500	_	_
480.134431	128.22	<.00017202.016458	15	Accession	
Total	17	7211.661458			

Appendix 5:

Combine analysis for plant infested-counts: (Table,5)

1st **count**

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob.
seasons		216.921812	108.46090	12.53	<.0001
Rep	2	6.38722	---		
868.35733	100.30 13025.36000	15	Accession		<.0001
Accession*season	47	352.04042	11.73468	1.36	0.1361
Total	66	13600.70945			

2nd **count**

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob.
seasons		138.080422	69.04021	11.46	<.0001
Rep	2	13.01167	---		
1064.68281	176.70 15970.24222	15 Accession			<.0001
Accession*season	47	354.57069	11.81902	1.96	0.0075
Total	66	16475.905			

3rd **count**

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob.
seasons		197.688472	98.84424	16.79	<.0001
Rep	2	1.75014	---		
1439.02252	244.39 21585.33778	15 Accession			<.0001
Accession*season	47	482.27597	16.07587	2.73	0.0001
Total	66	22267.05236			

4th count

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

---

seasons 213.080972 106.54049 15.02 <.0001

Rep 2 7.63764 ---

1869.48359 263.64 28042.25382 15 Accession <.0001

Accession*season 47 552.56347 18.41878 2.60 0.0002

Total 66 28815.5359

5th count

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

---

seasons 278.007922 139.00396 9.79 <.0001

Rep 2 10.44875 ---

2643.89607 186.13 39658.44111 15 Accession <.0001

Accession*season 47 699.02764 23.30092 1.64 0.0376

Total 66 40645.92542

mutawsit

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

---

seasons 188.667922 94.33396 24.67 <.0001

Rep 2 5.75792 ---

1509.07751 394.71 22636.16271 15 Accession <.0001

Accession*season 47 356.27875 11.87596 3.11 <.0001

Total 66 23186.8673

Appendix 6: Mean Number of mine infested by tomato leaf miner *T. absoluta* from different tomato accessions in Kassala State, Sudan season, (2017-2018)

Table(6)1st count

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 1.7029170.851458 __ __ 125.790097 41.89 <.0001

1886.85145815 Accession

Total 17 1888.554375

2nd count

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 0.351667 0.175833 __ __ 128.710431 82.82<.0001
1930.65645815 Accession

Total 17 1931.008125

3rd count

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 6.425417 3.212708 __ __ 168.656097 98.04<.0001
2529.84145815 Accession

Total 17 2536.266875

4th count

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 3.071250 1.535625 __ __ 212.009722 114.49<.0001
3180.14583315 Accession

Total 17 3183.217083

5th count

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 1.051250 0.525625 __ __ 266.408542 163.08<.0001
3996.12812515 Accession

Total 17 3997.179375

mutawsit

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 1.010417 0.505208 _ _

175.858986 119.82 <.00012637.884792 15 Accession

Total 17 2638.895209

Appendix 7: Mean Number of mine infested by tomato leaf miner *T. absoluta* from different tomato accessions in Kassala State, Sudan season, (2018-2019)

Table(7) **1st count**

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 1.1816670.590833 __ __ 120.807944 46.92 <.0001
1812.11916715 Accession

Total 17 1813.300834

2nd **count**

Surce Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 2.711667 1.355833 __ __ 134.661875 112.23<.0001
2019.92812515 Accession

Total 17 2022.639792

3rd **count**

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 1.475417 0.737708 __ __ 178.823056 177.06<.0001
2682.34583315 Accession

Total 17 2683.82125

4th **count**

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 7.470417 3.735208 __ __ 225.063944 183.23<.0001
3375.95916715 Accession

Total 17 3383.429584

5th **count**

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 1.755000 0.877500 __ __ 282.662542 226.95<.0001
4239.93812515 Accession

Total 17 4241.693125

mutawsit

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 0.981667 0.490833 _ _

183.242319 230.41 <.00012748.634792 15 Accession

Total 17 2749.616459

Appendix (8) : Mean Number of mine infested by tomato leaf miner *T. absoluta* from different tomato accessions in Kassala State, Sudan season, (2019-2020)

Table(8)

1st **count**

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 10.8004175.400208 __ __ 95.820389 29.13 <.0001
1437.30583315 Accession

Total 17 1448.10625

2nd**count**

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 0.095417 0.047708 __ __ 122.501556 15.06<.0001
1837.52333315 Accession

Total 17 1837.61875

3rd**count**

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 10.473750 5.236875 __ __ 177.859056 35.46<.0001
2667.88583315 Accession

Total 17 2678.359583

4th **count**

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 6.491250 3.245625 __ __ 234.506542 56.69<.0001
3517.59812515 Accession

Total 17 3524.089375

5th **count**

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 1.923750 0.961875 __ __ 322.467556 67.85<.0001
4837.01333315 Accession

Total 17 4838.937083

mutawsit

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 0.466250 0.233125 _ _

180.032431 60.01 <.00012700.486458 15 Accession

Total 17 2700.952708

Appendix 9:

Combine analysis for mine active infested-counts: (Table,9)

1st **count**

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

----

seasons 84.8968062 42.448403 14.37 <.0001

Rep 2 2.071806 ---
333.310958 112.86 4999.664375 15 Accession <.0001
Accession*season 47 136.612083 4.553736 1.54 0.0599

Total 66 5223.24507

2nd count

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob.
	seasons	56.0962502	28.048125	8.02	0.0006
Rep	2	1.242917	---		
378.801315	108.36	5682.019722 15	Accession		<.0001
Accession*season	47	106.088194	3.536273	1.01	0.4641
Total	66	5845.447083			

3rd count

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob.
	seasons	14.4079172	7.203958	2.79	0.0662
Rep	2	8.463750	---		
518.749106	201.24	7781.236597 15	Accession		<.0001
Accession*season	47	98.836528	3.294551	1.28	0.1863
Total	66	7902.944792			

4th count

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob.
	seasons	6.0018062	3.000903	1.26	0.2896
Rep	2	8.900139	---		
663.839144	277.77	9957.587153 15	Accession		<.0001
Accession*season	47	116.115972	3.870532	1.62	0.0416
Total	66	10088.60507			

5th count

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-value	Prob.
	seasons	6.533752	3.26688	9.79	.001
Rep	2	1.59542	---		
862.19719	186.13	12932.95778 15	Accession		<.0001
Accession*season	47	140.12181	4.67073	1.89	0.0108
Total	66	13081.20876			

mutawsit

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

----

seasons 19.2066672 9.603333 5.70 0.0046

Rep 2 1.846667---

534.008255 316.70 8010.123819 15 Accession <.0001

Accession*season 47 76.882222 2.562741 1.52 0.0663

Total 66 8108.059375

Appendix (10) : Mean percentage fruits infested by tomato leaf miner *T. absoluta* from different tomato accessions in Kassala State, Sudan season, (2017-2018/ 2018-2019/2019-2020)

Table(10)

season 2017 – 2018

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 1.576250 0.788125 __ __ 288.292444 10.04<.0001

4324.38666715 Accession

Total 17 4325.962917

season 2018 – 2019

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 8.425417 4.212708 __ __ 378.127111 170.29<.0001

5671.90666715 Accession

Total 17 5680.332084

season 2019 – 2020

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 0.341250 0.170625 __ __ 353.923500 131.15<.0001

5308.85250015 Accession

Total 17 5309.19375

Combine analysis for fruit infested:

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

seasons 102.460562 51.23028 4.74 0.0110

Rep 2 2.67722 ---

993.01257 91.80 14895.18861 15 Accession <.0001

Accession*season 47 409.95722 13.66524 1.26 0.1974

Total 66 15407.60639

Appendix (11) : Number of hairs/cm2 of leaves of accessions and hybrids of tomato evaluated against *Tuta absoluta* , Kassala, Sudan.

Figure(5)

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 0.48500000 0.24250000 __ __ 1.44261111 4.05

0.0005 21.63916667 15 Accession

Total 17 22.12416667

Appendix (12) :fruit diameter of some tomato accessions evaluated against leaf miner *T. absoluta* for three consecutive season in kassala state, Sudan.

Table(11)

season 2017 – 2018

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 0.12166667 0.06083333 __ __ 3.42576389 78.35<.0001

51.3864583315 Accession

Total 17 51.508125

season 2018 – 2019

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 0.18041667 0.09020833 __ __ 3.27594444 78.02<.0001

49.1391666715 Accession

Total 17 49.31958334

season 2019 – 2020

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 0.04541667 0.02270833 __ __ 3.38333333 84.50<.0001
50.75000000 15 Accession

Total 17 50.79541667

Combine analysis for fruit diameter :

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

----

seasons 1.84430562 0.9221528 22.06 <.0001

Rep 2 0.1905556---
0.0952778 238.18 149.3510417 15 Accession <.0001
Accession*season 47 1.9245833 0.0641528 1.53 0.0619

Total 66 153.3104862

Appendix (13) : Total Soluble Solid (TSS) of some tomato accessions evaluated against infestation by tomato leaf miner, *tuta absoluta* in Kassala State, Sudan for the three consecutive.

Table(12)

season 2017 – 2018

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 0.15791667 0.07895833 __ __ 1.18331944 24.28<.0001
17.7497916715 Accession

Total 17 17.90770834

season 2018 – 2019

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 0.31500000 0.15750000 __ __ 1.21365278 33.76<.0001
18.2047916715 Accession

Total 17 18.51979167

season 2019 – 2020

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 0.06125000 0.03062500 __ __ 0.96488889 18.03<.0001
14.47333333 15 Accession

Total 17 14.53458333

Combine analysis for TSS :

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

----

seasons 6.418472222 3.20923611 68.16 <.0001

Rep 2 0.25388889---

3.17953704 67.53 47.69305556 15 Accession <.0001
----Accession*season 47 2.73486111 0.09116204 1.94 0.0086

Total 66 57.10027778

Appendix (14) : Number of yield by tomato leaf miner *T. absoluta* from different tomato accessions in Kassala State, Sudan season, (2017-2018/ 2018- 2019/2019-2020)

Table(13)season 2017 – 2018

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep2 0.03791667 0.01895833 __ __ 5.44000000 53.53<.0001
81.6000000015 Accession

Total 17 81.63791667

season 2018 – 2019

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep2 0.00541667 0.00270833 __ __ 6.33476389 312.61<.0001
95.0214583315 Accession

Total 17 95.026875

season 2019 – 2020

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 1.14541667 0.57270833 __ __ 5.94376389 14.46<.0001
89.15645833 15 Accession

Total 17 90.301875

Combine analysis:

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

----

seasons 18.06097222 9.0304861 50.69 <.0001

Rep 2 0.4276389---
17.0891111 95.93 256.3366667 15 Accession <.0001
Accession*season 47 9.4412500 0.3147083 1.77 0.0203

Total 66 284.2665278

Chemical Constituents Analysis:

Appendix (15): Lycopine Constituents in tomato accession evaluated against Tuta absoluta , Kassala, Sudan.

Figure (8)

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 0.042279 0.021139 __ _ 11.9462067 345.40<.0001179.1931000
15 Accession

Total 17 179.2353792

Appendix (16): Tannin Constituents in tomato accession evaluated against Tuta absoluta , Kassala, Sudan.

Figure (9)

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 7.3432667 3.6716333 __ __ 33.1781328 11.68<.0001
497.6719917 15 Accession

Total 17 505.0152584

Appendix (17): Caroten Constituents in tomato accession evaluated against Tuta absoluta , Kassala, Sudan.

Figure (10)

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 66.635579 33.317790 __ __ 96.867828 2.83
0.00751453.017415 15 Accession

Total 17 1519.652994

Appendix (18): Scorbic acid Constituents in tomato accession evaluated against Tuta absoluta , Kassala, Sudan.

Figure (11)

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 0.0270292 0.0135146 __ __ 20.5083506 18.07<.0001
307.6252583 15 Accession

Total 17 307.6522875

Appendix (19) : Number of yield by tomato leaf miner *T. absoluta* from different tomato accessions in Kassala State, Sudan season, (2017-2018/ 2018- 2019/2019-2020)

Table(13)

season 2017 – 2018

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 0.03791667 0.01895833 __ __ 5.44000000 53.53<.0001
81.6000000015 Accession

Total 17 81.63791667

season 2018 – 2019

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 0.00541667 0.00270833 __ __ 6.33476389 312.61<.0001
95.0214583315 Accession

Total 17 95.026875

season 2019 – 2020

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 1.14541667 0.57270833 __ __ 5.94376389 14.46<.0001
89.15645833 15 Accession

Total 17 90.301875

Combine analysis:

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

----

seasons 18.06097222 9.0304861 50.69 <.0001

Rep 2 0.4276389---

17.0891111 95.93 256.3366667 15 Accession <.0001

Accession*season 47 9.4412500 0.3147083 1.77 0.0203

Total 66 284.2665278

Appendix (20)

Table (14)

. Effect of water extracts of Wenca, water extract Datura, Neem seed oil and Dancid®**on mean number of active mines of *T. absoluta*/plot on tomato plants**

Pre- count mean :

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 2.817333331.40866667 __ __
17.122666678.570.012368.49066667 4 treatment

Total 6 71.308

First post spray after 48 hour:

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 3.33333331.6666667 __ _
64.233333319.270.0004256.9333333 4 treatment

Total 6 260.2666666

First post spray after 72 hour:

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 4.93333332.4666667 __ _
110.100000039.32<.0001440.4000000 4 treatment

Total 6 445.3333333

First post spray after 7 days:

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 8.53333334.2666667 __ _
156.566666732.85<.0001626.2666667 4 treatment

Total 6 634.8

Second post spray after 48 hour:

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 1.20000000.6000000 __ _
186.433333350.62<.0001745.7333333 4 treatment

Total 6 746.9333333

Second post spray after 72 hour:

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 12.1333336.066667 __ _
295.50000044.44<.00011182.000000 4 treatment

Total 6 1194.133333

Second post spray after 7 days:

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 2.8000001.400000 __ __
369.93333370.69<.00011479.733333 4 treatment

Total 6 1194.133333

Third post spray after 48 hour:

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 0.9333330.466667 __ _
363.766667248.02<.00011455.0666674 treatment

Total 6 1456

Third post spray after 72 hour:

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 0.4000000.200000 __ _
514.900000115.71<.00012059.6000004 treatment

Total 6 2060

Third post spray after 7 days

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 0.9333330.466667 __ _
832.900000273.08<.00013331.6000004 treatment

Total 6 3332.533333

Table (15):

Effect of water extracts of Wenca, water extract Datura, Neem seed oil and Dancid® **on mean percent of plants infested by *T. absoluta*/plot on tomato plants.**

Pre- count

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 52.13733333 26.06866667 __ _
9.422666670.440.777737.69066667 4 treatment

Total 6 89.828

First post spray after 48 hour:

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 10.08533335.0426667 __ _
188.00900005.230.0228752.0360000 4 treatment

Total 6 762.1213333

First post spray after 72 hour:

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 118.27600059.138000 __ _
323.24433336.24<.00011292.9773334 treatment

Total 6 1411.253333

First post spray after 7 days:

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 16.5053338.252667 __ _
474.37900046.79<.00011897.5160004 treatment

Total 6 1914.021333

Second post spray after 48 hour:

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 9.7333334.866667 __ _
571.52100042.48<.00012286.084000 4 treatment

Total 6 2295.817333

Second post spray after 72 hour:

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 51.49733325.748667 __ _
1146.16266790.22<.00014584.650667 4 treatment

Total 6 4636.148

Second post spray after 72 hour:

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 50.565333 25.282667 __ __
1337.592333173.05<.00015350.369333 4 treatment

Total 6 5400.934666

Third post spray after 48 hour:

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 8.9973334.498667 __ __
977.12400065.33<.00013908.4960004 treatment

Total 6 3917.493333

Third post spray after 72 hour:

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 80.50800040.254000 __ _
1736.760667188.36<.00016947.0426674 treatment

Total 6 7027.550667

Third post spray after 7 days:

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 43.33333321.666667 __ _
2333.448333274.74<.00019333.7933334 treatment

Total 6 9377.126666

Appendix (21)

Table 16. Effect of water extract of Vinca, water extract of Datura, Neem seed oil and Dancid® on (%) of fruits damaged by *T. absoluta*

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 169.40800084.704000 __ _
277.1823333.560.05951108.7293334 treatment

Total 6 1278.137333

Appendix (22)

Table 17. Effect of application of water extracts of Vinca, water extract of Datura, Neem seed oil and Dancid® to control *T. absoluta* on tomato yield (Tons/ha)

Source Degrees of Freedom Sum of Squares Mean Square F-value Prob.

Rep 2 0.697333330.34866667 __ _
97.3773333324.34433333179.88<.00014 treatment

Total 6 98.07466666