Advanced Journal of Agricultural Research (AJAR) ISSN 2367-9816, Vol. 8(4), pp. 237-243, October, 2021.
Available online at www.advancedscholarsjournals.org © Advanced Scholars Journals

Full length Research paper

Effect of bio-pesticides and antagonistic synthetic pesticides in managing tomato pests and fungal diseases under agro-climatic conditions of Huye District-Rwanda

Ndaruhutse Felicien[1]*, Mukakalinda Aline[1], Cyiza Vedaste[2] and Maniraho Eric[3]

[1]Rwanda Polytechnic/ Integrated Polytechnic Regional College/ Department of Agricultural engineering
[2]Rwanda TVET Board/Department of Curriculum development
[3]University of Rwanda/ College of Agriculture, Animal Sciences and Veterinary Medicine

Accepted 11th October, 2021

In Rwanda many farmers use chemicals in tomato production to control diseases and pests as it appears in many research regionally; and those chemicals are not environmentally friendly. Apparently, there is no research done in Rwanda on effect of bio-pesticides use which farmers can refer to for improving their tomatoes production. The present study was under taken to evaluate the effectiveness of some bio-pesticides in managing pests and diseases of tomato under field conditions. The field experiments were conducted over two cropping cycles between October 2020 and June 2021 in the field of Integrated Polytechnic Regional College Huye, with a long history of tomato growing. The effects of selected bio-pesticides were observed. Bio-pesticides reduced the intensity of late blight levels by 63% and 70% respectively and early blight by 44% and 33% respectively. Bio-pesticides reduced the population of Tuta absoluta and white flies by 65%, and 73% respectively. The Bio-pesticides reduced pest and disease damage on fruits by up to 50% and 67% respectively. Success of bio-pesticides compared positively with that of the synthetic pesticides. The results showed that bio-pesticides from natural environments can be incorporated in integrated pest and disease management in tomato and can help reduce overuse of synthetic pesticides.

Keywords: Synthetic pesticides, Bio-pesticides, Tomato pests, Tomato diseases

INTRODUCTION

Tomato is one of the most important vegetables in Rwanda and is Rwanda's second largest vegetable in volume produced and area cultivated (after cabbage) and is the largest in value (NAEB, 2020). It's grown for its diverse use both for the fresh market and processing industries in the last years (NEAB, 2018). The small-scale farmers are mainly grown tomatoes as a source of income. Tomato is affected by insect pests and disease pathogens which harmfully distress its quality, quantity, productivity and the losses can go up to 60-100% (Ochilo et al., 2018; Pratt et al., 2017; USAID, 2015; Islam et al., 2013). Tomatoes are subject to insect pests that affect plants directly by feeding and indirectly by transmission of diseases from the time of emergence up to harvesting (Khan, 2018; Bhattacharjee and Dey, 2014). Insect pests such as leaf miners, Tuta absoluta, aphids and flea beetles affect the foliage while fruit borers affect the tomato fruits (Kandil et al.,2020; Syed, 2015; Taha et al., 2013). Some of the pathogens that affect tomatoes have a sophisticated morphology which makes them complicated to manage in the field (Stangarlin et al., 2011). Farmers involved in tomatoes production find using synthetic pesticides the most convenient way have of managing these pests and diseases (Mizubuti et al.,2007) such as early bright and late blight (*Phytophthora infestans* Mont. De Bary) which are managed by a mixture of protective and curative synthetic fungicides yet the losses in the field are still high (Kansiime et al., 2017; Rutikanga, 2015).

Since synthetic pesticides partially solve the threat, they

*Corresponding Author's:E-mail: nfelicien13@gmail.com

also have negative effect on environment due to non-biodegradability, health hazards to the farmers and consumers, pollute the environment, toxicity to non-target natural enemies and other beneficial organisms (Dar SA et al. 2021; Saberi et al., 2020; Bhattacharjee and Dey, 2014). They are detrimental to applicants and continuous application lead to resistant build-up among the pests as well as pathogens (Wagnitz, 2014; Engindeniz et al., 2013 Stangarlin et al., 2011). Many farmers do not use protective equipment while applying the chemicals and do not observe dilution instructions thus compromising their own safety (Damalas and Koutrobous, 2015; Goufoetal.,2008). Target markets have set strict quality requirements and require the food produce to be safe, clean and healthy for consumption (Kumar et al., 2021; Kimani, 2014). These requirements have become stricter specifically for the amounts of chemical residues in fresh vegetables (Chen, 2018; European Commission, 2012).

Synthetic pesticides could be complemented with bio-pesticides as substitute pest and disease management products due to non-compliance with the market requirements (Engindeniz et al., 2013).

Biopesticides are agents that are obtained from plants, microorganisms and animals, such as bacteria, cyanobacteria, and microalgae and are used to control crop pests and pathogens (EPA,2021). In addition, bio-pesticides have been getting much practical consideration as alternates to synthetic chemical plant protection products due to biodegradability and reduction of risks associated with use of synthetic chemicals (Liu et al., 2021; Rutikanga,2015). Bio-pesticide can also decompose quickly without leaving problematic residues and hence can reduce the use of synthetic pesticides as an integral component of integrated pest management program. In this context, the present study was undertaken in order to find out the effect of commercial botanical pesticides and antagonistic synthetic pesticides for controlling Early blight, late bright, Leaf spot, Fruit spot, and another related pest.

MATERIALS AND METHODS

Experimental site and materials

The field experiments were conducted in Integrated Polytechnic Regional College (IPRC) Huye farm with along history of tomato production. The experiments were carried out over two cropping cycles between October 2020 and July 2021. Commercial bio-pesticides and synthetic pesticides were evaluated for their pest and disease management efficacy. Commercial bio-pesticides evaluated were two isolates of *Trichoderma labelled* as *Trichoderma* Sp1 and *Trichoderma* Sp2; commercial botanical formulation (Achook 0.15 EC®- *Azadirachta indica*) and Commercial botanical formulation (Pyrethrin (75 g/l). Synthetic pesticides for controlling fungus were Ridomil Gold®(4% Metalaxyl-M and 64% Mancozeb) and Isacop 80 WP®(Copperoxy chloride-50% metallic copper) and synthetic insecticide was Confidor SC 200® (0.125g/lImidacloprid). The synthetic pesticides were standard checks while plots treated with water only were the negative control. The treatments were laid out in randomized complete block design with 5 treatments (T) including check plots replicated three times. To: Untreated control plots, T1: Commercial microorganism Trichoderma sp 1, T2: Commercial microorganism Trichoderma sp 2, T3: commercial botanical formulation (Achook 0.15 EC®- Azadirachta indica) plus Commercial botanical formulation (Pyrethrin (75 g/l) and T4: was the combination of synthetics fungicides and insecticide (Isacop 80 WP® and Ridomil Gold®) and (Confidor SC 200®) respectively. The commercial products were applied according to the manufactures' guidelines. Treatment application was initiated two weeks after transplanting tomato seedlings and afterward the successive application was done at one-week intervals. The agronomic practices such as fertilizer application, watering and weeding were carried out as required. Data was collected on pest damage, disease distribution, incidence and severity and fruit yield.

Assessment of pest population and damage

Assessment of pests such as leaf miner (*Tuta absoluta*) and white flies (*Bemisia tabaci*) started from the third week after transplanting until the end of harvesting as described by NICRA (2012). Eight plants were sampled from the central rows in each plot. The Eight plants were tagged and two leaflets were selected from each of the leaves on which the number of white fly nymphs was counted on the underside and this was done during the early morning. Damage caused by *Tuta absoluta* was assessed as the number of mines on all the leaves of the eight plants sampled. Assessment of pest damage and insect pests was done on a weekly basis before the successive treatment application was done.

Assessment of disease distribution, incidence and severity

The most prevalent diseases were Early blight and late blight and they were assessed on a weekly basis starting three weeks after transplanting over a period of 9 weeks from the first observation of disease. Distribution of each disease was assessed on a scale of 0-2, where 0 = no disease in the whole plot,1 = disease present in spots within a plot, and 2 = disease distributed over the whole plot (Bock et al., 2010). The occurrence of new case of disease estimated in percent values here after called disease incidence were then converted into proportion, where 0 = no disease and 1 =

all plants infected. Disease incidence was assessed as the total number of plants displaying infection out of the total number of plants per plot and converted to percent, where0 = no disease and 100% = all plants showing infection. Diseases verity was assessed on eight plants randomly selected from the central rows within each plot on a 0-5 scale modified from Horse fall and Barret (1945) and Henfling (1987), where 0 = no disease, 1 = < 20% leaf area infection, 2 = 21-40% leaf area infected, 3 = 41-60% leaf area infected, 4 = 61-80% leaf area infected, 5 = 81-100% leaf area infected.
The scores of disease distribution, incidence and severity were used to calculate percent disease index (Sundaramoorthy and Balabaskar, 2013) as follows:

$$Disease\ index = \frac{Distribution\ score\ + Incidence\ score\ + Severity\ score}{Maximum\ disease\ score} * 100$$

Disease distribution had a maximum score of 1, incidence had a maximum score of 2 while disease severity had a maximum score 5, thus giving total cumulative maximum disease index of 8.

Assessment of fruit yield and quality

The weight of the harvested fruits was recorded and later categorized into different grades according to FAO (2015). Grading was done as follows: Grade 1 (No decay, no foreign materials, no injury, fairly firm and not over ripe, attractive and well-shaped, at least 50mm, fairly uniform in size and colour); Grade 2 (same characteristics as class 1 but 40mm in size); Grade 3 (Same characteristics as class 1, but 30mm in size). The grades 1 up to grade 3 were the marketable portion whereas the grade 4 were those with pest, disease and any other form of damage were the unmarketable portion.

Data collection and analysis

After collecting data from sampled plants per each replication, data on populations of white fly nymphs and leaf minor damage on leaves were collected on weekly basis commencing third weeks after transplanting as well as distribution, incidence and severity of early and late blight diseases. Yield categories were also collected and all the data was stored in Microsoft Excel sheets and subjected to analysis of variance using Gen Stat® 15th Edition. Means were separated using Fischer’s Protected LSD (Steel and Torrie, 1990).

RESULTS AND DISCUSSION

Effect of bio-pesticides and antagonistic synthetic pesticides in reducing populations of tomato pests

Bio-pesticides were significantly (p ≤0.05) reducing the populations of white flies and *Tuta absoluta* damage compared to the negative control (Table 1). Commercial bio-pesticides were more effective in reducing populations of insects compared to the antagonistic synthetic pesticides with having reductions of up to 73% of white flies and 65% of *Tuta absoluta*. The antagonists reduced the populations by up to 32% and 25% in white flies and *Tuta absoluta* respectively (Table1).
These findings were in agreement with those of EPPO, 2005 and UN, 2015 which reported that the use of bio-pesticides is gaining momentum because they can be efficiently used in sustainable agricultural practices and reduced populations of tomato weevils. Similarly, result was also confirmed by Gupta et al., 2013 who revealed that bio-pesticides are going to play an imperative role in pest management program of horticulture crops.
There was no much difference in the effectiveness of the bio-pesticides with the commercial synthetic pesticides of Confidor SC 200®, Ridomil Gold® and Isacop 80 WP®.
Bio-pesticides were significantly (p≤0.05) reducing the populations of the two insect pests compared to all the other treatments. This treatment was more effective on Tuta absoluta.
The synthetic pesticides reduced the populations of the two insect pests compared to the negative controls and Trichoderma sp1 and sp 2 with greater effectiveness. The issue of synthetic pesticide residue is a serious hazard to environment and human health.
It is fortunate that the excessive use of chemical pesticides in crop protection to reduce the damage caused by pathogen and pests, pose many long terms risks to living beings such as cancers (Kalafati et al., 2018).
It is therefore bossy that additional environmentally friendly approaches of crop protections are accepted, such as integrated pest management (IPM) methods, comprising the use of bio-fertilizers and bio-pesticides (Kundoo et al., 2018).
A commercial botanical with a combination of Achook 0.15 EC (neem) and pyrethrin (75g/l) show good efficacy against T. absoluta and white flies compared to other treatments.
These findings agree with those of Nashwa and Abo-Elyous (2012) who stated that fresh garlic juice reduced populations of maize weevils while Gupta and Dikshit (2010) stated that a commercial botanical formulation was low as compared to the synthetic insecticides but those bio-pesticides were helpful to some level for control of tomato fruit borer and white flies due to organic in nature the bio-pesticides have environmental safe and less health hazards while the synthetic insecticides have lots of ill effects on environment.

Table1: Mean Number of white fly and *Tuta absoluta* on tomato crop treated with bio-pesticides and synthetic pesticides

Treatments	White flies		Tuta absoluta	
	Cropping cycle1	Cropping cycle2	Cropping cycle 1	Cropping cycle 2
Trichoderma sp1	32.3b	34.1b	36.6b	30.2bc
Trichoderma sp2	33.7b	35.0b	37.5b	29.2c
Bio-pesticides *	25.6cd	22.4d	21.1d	22.5cd
Synthetics*	28.1c	26.0cd	25.2c	24.1cd
Control	41.8a	43.2 a	42.1a	44.3a
LSD (p ≤0.05)	3.5	4.2	6.3	7.2
CV(%)	8.1	12.1	9.6	15.1

Means followed by the same letter(s) within each column do not differ significantly at (p ≤ 0.05). Bio-pesticides was a combination of (Achook 0.15 EC®- *Azadirachta indica*) and (Pyrethrin (75 g/l). Synthetics* was a combination of Confidor SC 200®, Ridomil Gold® and Isacop 80 WP®

Effect of Bio-pesticides and commercial synthetic pesticides in management of early and late blight of tomato

Bio-pesticides and synthetic pesticides reduced intensity of early blight. There were significant (P≤0.05) differences in cropping cycle one among treatments whereas cropping cycle two shown no significant (p≥0.05) differences among the treatments (Figure 1). *Trichoderma* sp1 and sp2 were effective in reducing early blight in the field (Figure1) relative to the bio-pesticides and non-treated controls. Commercial botanical pesticides and synthetic pesticides reduced late blight intensity (Figure 2) compared other untreated control. One isolate of *Trichoderma sp1* was the most effective followed by synthetic pesticides and bio-pesticides compared to the untreated control.

Mizubuti et al., 2007 revealed that effectiveness of the Trichoderma sp1 and sp2 used as microbial bio-pesticides due to its organic acid in reducing populations of insect pests in the field is attributed to the presence of volatile compounds such as alkaloids, tannins and saponins. Those biopeptides are also considered as one of the effective strategies to fight soil- borne fungal pathogens, subsequently several investigators have revealed Trichoderma spp. as biological control agents that can be used to control many phytopathogenic fungi, such as Fusarium species and other fungal diseases (El-Komy et al., 2015; Li et al., 2018). Vinale et al., 2008 revealed that Trichoderma sp and /or its citric acid can also decrease disease parameters and the pathogenic fungus including early bright and late bright fungal disease in tomato crop. The result may be also attributed to the strong capacity of Trichoderma sp to uptake nutrients from soil which makes it more competitive than other soil microbes. Moreover, organic acid and citric acid in specific were considered as antimicrobial agents (Coban, 2020). Trichoderma sp has been shown as a micro parasitic species that is well recognized and widely used for its ability to avoid the growth of plant pathogens as well as protection of vegetables and other crops (Saber et al., 2017; Skaptsov et., 2018). Therefore, Trichoderma sp have commercially been used for plant protection and yield maximization due to its environmentally friendly (Sharma, 2018).

Both commercial botanical formulation (Achook 0.15 EC and pyrethrin) and synthetic fungicide reduced the levels of early blight and late bright compared to the untreated control. However, disease reduction was not significant on synthetic pesticide compared with bio-pesticide. Goufoetal. (2010) reported that the effectiveness of synthetic fungicides in reducing disease levels is comparable to that of commercial botanical formulation.

In his report he mentioned that commercial botanical formulation having similar results with synthetic fungicides against late blight in Tomato crop and these results confirmed with findings of Nashwa and Abo-Elyousr (2012) who reported the severity reduction of early blight after evaluation of neem, garlic, thorn apple and other plant extracts.

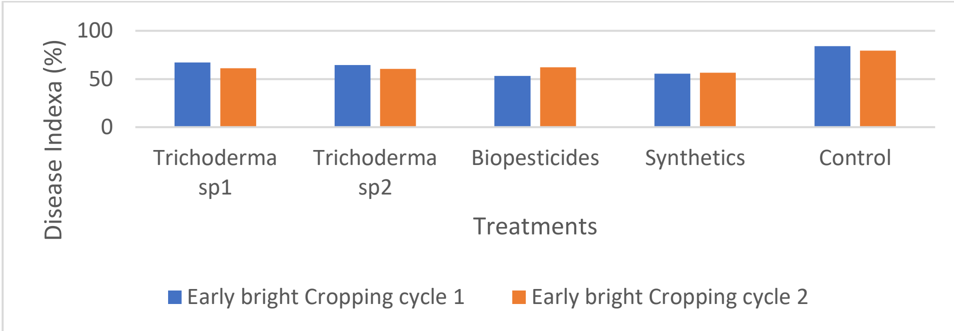

Figure 1: Percentage disease index for Early blight in tomatoes applied with botanical bio-pesticides and synthetic pesticides

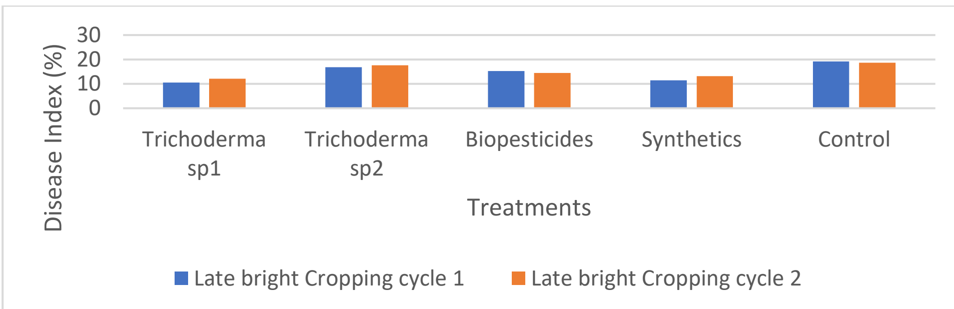

Figure 2: Percentage disease index for late blight in tomatoes applied with botanical bio-pesticides and synthetic pesticides

Effect of bio-pesticides and antagonistic synthetic pesticides for sustainable and improving tomato fruit yield and quality

The analysis of variance of the data showed significant differences (p≤0.05) in fruit yield and quality of tomatoes sprayed with different commercial botanical pesticides and synthetic fungicides. It was evident from the mean yield that tomato plants treated with synthetic pesticides and a commercial botanical formulation pesticide, had the highest yield of grade 1 and 2 of marketable fruits while yield from plants untreated had a significantly (p ≤0.05)higher yield of grade 3 and unmarketable fruits. Similarly with findings by Stangarlin et al., (2011) who revealed that there were no yield differences in fruits harvested from plants sprayed with several bio-pesticides. Commercial botanical pesticides reduced pest infestations on fruit yield with more than 43.5% and disease infections by more than 59% (Table 2). Majority of the yield was found under the grade 3 with the highest being from the synthetic pesticides and Trichoderma sp2 respectively. The increase in yield and quality improvement are as a result of reduced pests and diseases during growth and fruit expansion. Different authors reported that reduced populations of pests (Casswell 2015) and diseases (Nashwa and Abo-Elyousr, 2012) have also reported a significant increase in tomato yield production. Bio-pesticides have been reported to have growth preferment effect upon using microbial pesticides in diseases and pest management (Singh et al., 2015).

Table2: Yield (Kg/ha) for different grades harvested from tomato crop treated with bio-pesticides and antagonistic synthetic pesticides

Treatments	Cropping cycle 1				Cropping cycles 2			
	Grade 1	Grade 2	Grade 3	Grade 4	Grade 1	Grade2	Grade 3	Grade 4
Trichoderma sp1	430.2c	482.5a	1120cd	2345.8c	468.0c	410.4b	1202c	2214.5c
Trichoderma sp2	320de	100.5ef	1548.5b	3101.5a	308.2de	84.6e	1730.1ab	2930.3a
Bio-pesticides*	521.5ab	432.3ab	620.1ef	2010.6d	550.2ab	438.4a	610.6ef	2035.5de
Synthetics*	543.1a	390.7cd	1738.5a	2590.5b	601.5a	353.1cd	1893.2a	2574.5ab
Control	91.5f	63.2ef	643.5ef	869.7ef	68.1f	53.9ef	746.7de	1630.7f
LSD (P≤ 0.05)	18.2	20.1	68	118.6	30.1	17.2	80.2	121.1
CV (%)	4.1	5.9	5.6	12.1	3.6	2.9	6.1	15.1

Means followed by the same letter(s) within each column do not differ significantly at (p ≤ 0.05). Bio-pesticides was a combination of (Achook 0.15 EC®- *Azadirachta indica*) and (Pyrethrin (75 g/l). Synthetics* was a combination of Confidor SC 200®, Ridomil Gold® and Isacop 80 WP®

CONCLUSION

The study showed that bio-pesticides and antagonistic synthetic pesticides are successful in reducing pest populations, disease levels and increase crop yield. Thus, they can be incorporated in integrated pest and disease management programs, where by reducing the over use of synthetic pesticides which are harm to human health and environment and leave harmful residues on produce. This would help to meet the quality requirements and hence improve access to international markets which will be resulting to the increase of small-scale tomato growers' income.

Conflict of interests

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

This project was funded by Strengthening Education for Agriculture Development (SEAD) project/Rwanda Development Board for Capacity Building in Agriculture Grant under the Competitive Grants System, Project under Research Capacity and Innovation Development (RCID) 4th Cycle.

REFERENCES

Bhattacharjee R, Dey U (2014). An overview of fungal and bacterial bio-pesticides to control plant pathogens and diseases. Afric.J. ofMicro. Res.8(7):1749-1769.

Casswell L (2015). "Kenyan bio-pesticides success brings hope for UK crop pest control", Farmers Weekly, Wednesday, 21st January 2015.

Chen, J (2018). Bio-pesticides: Global Markets to 2022; Report Code CHM029G; BCC Research: Wellesley, MA, USA, 2018.

Coban HB (2020). Organic acids as antimicrobial food agents: Applications and microbial productions. Bioprocess Biosyst. Eng. 43: 569–591.

Damalas CA, Koutroubas DS (2015). Farmers' Exposure to Pesticides: Toxicity Types and Ways of Prevention. Toxics4(1):1-10

Dar SA, Sajad HW, Sajad HM, Abid S, Tashi D, Tashi D (2021). Bio-pesticides: Mode of Action, Efficacy and Scope in Pest Management. J. Adv. Res. in Biochemistry and Pharmacology 2021; 4(1): 1-8

El-Komy MH, Saleh AA, Eranthodi A, Molan YY (2015). Characterization of novel Trichoderma asperellum isolates to select effective biocontrol agents against tomato Fusarium Wilt. Plant Pathol. J. 31: 50–60.

EngindenizS, OzturkGC(2013). An economic comparison of pesticide application for processing and table tomatoes, a case study for Turkey. J.ofPlantProt. Res.53(3):230-237

EPA (2021). Ingredients Used in Pesticide Products: Pesticides. What Are Biopesticides? Available online: https://www.epa.gov/ ingredients-used-pesticide-products/what-are-biopesticides (accessed on 26 September 2021).

European and Mediterranean Plant Protection Organization (EPPO), 2005, Data sheets on quarantine pests: *Tuta absoluta,* EPPO, Bulletin 35: 434-435

Fountain D E and Written S D, 2013, Conservation biological control and bio-pesticides in agriculture, Encyclopedia of Ecology, 744-747

European Commission (2012). Amending Annex, Ito Regulation (EC) No 669/2009 implementing Regulation (EC)No 882/2004 of the European Parliament and of the Council as regards the increased level of official controls on imports of certain feed and food of non-animal origin. Official Journal of the European Union. L. 350/44. 20/12/2012

FAO (2015). Handling of Fresh Fruits, Vegetables and Root Crops -A Training Manual for Grenada. TCP/GRN/2901- Agricultural Marketing Improvement.

Goufo P, Mofor TC, Fontem DA, Ngnokam D (2008). High efficacy of extracts of cameroon plants against tomato late blight disease. Agronomy for Sust. Develop. 28 (4):567-573

Gupta D (2010). Bio-Pesticides; An eco-friendly approach for pest control, Journal of Bio-pesticides 3: 186-188,

Henfling JW (1987). Late blight of Potato, Technical Bulletin No4, Int. Potato centre LimaPeru P25.

Horsefall JG, Barret RW (1945). An improved system for measuring plant disease. Phytopathology35:655.

Islam RMD ,Mondal C, Hossain I, Meah MB (2013). Organic management: An alternative to control late blight of potato and tomato caused by Phytophthorainfestans, International J. of Theoretical and AppliedSci. 5(2):32-42.

Kalafati L, Barouni R, Karakousi T, Abdollahi M, Tsatsakis A (2018). Association of pesticide exposure with human congenital abnormalities. Toxicol. Appl. Pharmacol. 346, 58–75.

Kandil MA, Rania NA, Moataz AMM (2020). Lethal and sub-lethal effects of bio-and chemical insecticides on the tomato leaf miner, Tuta absoluta (Meyrick) (Lepidoptera: Gelechiidae). Egyptian Journal of Biological Pest Control. (2020) 30:76 https://doi.org/10.1186/s41938-020-00278-1

Kansiime M, Mulema J, Karanja D, Romney D, Day R (2017). Crop Pests And Disease Management in Uganda:Status and Investment Needs. Platform for Agricultural Risk Management | Managing risks to improve farmers' livelihoods.

Khan RA (2018). Sustainable management approach for controlling thrips (Thy-sanoptera: Thripidae) and their transmitted to spoviruses in tomatoes in south Florida. Ph.D. Dissertation (in progress). Entomology and Nematology Department, University of Florida, Gainesville, Florida, USA.

Kimani V (2014). Bio-Pesticides development, use and regulation in Kenya, Regional ExpertsWorkshop on Development, Regulation and Use of Bio-Pesticides in

East Africa,22nd -23rd May, 2014, Nairobi, Kenya.
Kumar J, Ramlal A, Mallick D, Mishra V (2021). An Overview of Some Bio-pesticides and Their Importance in Plant Protection for Commercial Acceptance. Plants 2021, 10, 1185. https://doi.org/10.3390/ plants10061185.
Kundoo AA, Dar SA, Mushtaq M, (2018). Role of neonicotinoids in insect pest management: A review. J. Ent. and Zool. Studies 6(1): 333-9.
Li YT, Hwang SG, Huang YM, Huang CH (2018). Effects of Trichoderma asperellum on nutrient uptake and Fusarium wilt of tomato. Crop. Prot. 110: 275–282.
Liu X, Cao A, Yan D, Ouyang C, Wang Q, Li Y (2021). Overview of mechanisms and uses of biopesticides. Int. J. Pest Manag. 2021, 67, 65–72.
Mizubuti GSE, Junior VL, Forbes GA (2007). Management of late blight with alternative products, Pest Technology 1(2):106-116.
Nashwa S M A, Abo-Elyousr A M K (2012). Evaluation of various plant extracts against the early blight disease of tomato plants under green house and field conditions, Plant Protection Science 48(2): 74-79
Nashwa SMA, Abo-Elyous AMK (2012). Evaluation of various plant extracts against the early blight disease of tomato plants under green house and field conditions, Plant Prot. Sci 48(.2): 74-79.
National Agricultural Export Development Board (NAEB) (2020). Annual report 2019-2020
National Agriculture export Development (NAEB) (2018). Annual report 2017-2018
NICRA team of pest surveillance (2012). Manual for tomato pests surveillance, jointly published by National Centre for Integrated Pest management (NCIPM), New Delhi, Central Institute for Dryland Agriculture, Hyderabad, Indian Institute for Horticultural Research, Bengaluru and Indian Institute of Vegetable Research,Varanasi39 pp
Ochilo WN, Gideon N, Nyamasyo N, Kilalo D, Otieno W, Otipa M, Chege F, Karanja T, Eunice E, Lingeera K (2018). Characteristics and production constraints of smallholder tomato production in Kenya. Scientific African Journal .2: 2468-2276.
Pratt CF, Constantine KL, Murphy ST (2017). Economic impacts of invasive alien species on African smallholder livelihoods. Global Food Security. 14: 31-37.
Rutinganga (2015). Pesticides use and regulations in Rwanda status and potential for promotion of biological control methods. Kigali, Rwanda
Saber WIA, Ghoneem KM, Rashad YM, Al-Askar AA (2017). Trichoderma harzianum WKY1: An indole acetic acid producer for growth improvement and anthracnose disease control in sorghum. Biocontrol Sci. Technol. 27: 654–676.
Saberi F, Marzban R, Ardjmand M, Pajoum SF, Tavakoli O (2020). Optimization of culture media to enhance the ability of local Bacillus thuringiensis var. tenebrionis. J. Saudi Soc. Agric. Sci. 19: 468–475.
Sharma KK (2018). Trichoderma in agriculture: An overview of global scenario on research and its application. Int. J. Curr. Microbiol. Appl. Sci., 7:1922–1933.
Singh H, Al-Samarrai G F, Jaffar M H, Chemat M H, Islam A K M S (2015). Performance of five plant extracts on leaf cutting beetle Hypomycessquamosus on Harumanis 83 variety of mango in Perlis, Malaysia, International Journal of Agricultural Sciences and Research 3(1) 89-98.
Skaptsov M, Smirnov S, Kutsev M, Uvarova O, Sinitsyna T, Shmakov A, Matsyura A (2018). Antifungal activity of several isolates of Trichoderma against Cladosporium and Botrytis. Ukr. J. Ecol., 8: 88–91.
Stangarlin JR, Kuhn OJ, Assi L, Schwan-Estrada KRF (2011). Control of plant diseases using extracts from medicinal plants and fungi, Formatex 1033-1042.
Stangarlin JR, Kuhn OJ, Assi L, Schwan-Estrada KRF (2011). Control of plant diseases using extracts from medicinal plants and fungi, Formatex 1033-1042.
Steele RGD, *Torrie* JH (*1990*) Principles and Procedures of Statistics. 2nd Edition, McGraw-Hill Book Co Inc., New York.
Sundaramoorthy S, Balabaskar P (2013). Biocontrol efficacy of Trichoderma spp. against wilt of tomato caused by Fusarium oxysporum f. sp. lycopersici. J App Biol Biotech, 1 (03): 036-040.
Syed AHR, Saleem J (2015). Efficacy of some selected chemical insecticides and bio-pesticides against tomato fruit worm, (Heli cover paarmigera) under the agro climatic condition of Gilgit Baltistan, Pakistan. Journal of Entomology and Zoology Studies 2015; 3(4): 50-52
Taha AM, Afsah AFE, Fargalla FH (2013). Evaluation of the effect of integrated control of tomato leaf miner Tuta absoluta with sex pheromones and insecticides, Nature and Science 11(7): 26-29
The East African (2015). Kenya at risk of losing EU markets for peas, beans due to falling standard. 25th April 2015.
United Nations Department of Economic and Social Affairs. World Population Prospects (2015). The 2015 Revision, Key Findings and Advance Tables; Working Paper No ESA/P/WP; United Nations Department of Economic and Social Affairs: New York, NY, USA.
Vinale F, Sivasithamparam K, Ghisalberti EL, Marra R, Woo SL, Lorito M (2008). Trichoderma-plant-pathogen interactions. Soil Biol. Biochem., 40: 1–10.
WagnitzJJ (2014). Bio-pesticides use in IPM for low desert vegetable and fruit production, Paper AA13618603, Degree of Doctor of Philosophy in Plant Health, College of Agricultural Sciences and Natural Resources, ETD Collection for University of Nebraska, Lincon