Efficacy of Plant Extracts and Antagonistic Fungi in Managing Tomato Pests and Diseases under Field Conditions

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Abstract

The objective of this study was to evaluate the effectiveness of plant extracts and fungal antagonists in managing pests and diseases of tomato under field conditions. The extracts and the antagonists were evaluated for efficacy against synthetic pesticides under field conditions. Plant extracts reduced the population of whiteflies and Tutaabsoluta by 63% and 55%, respectively. Plant extracts and antagonistic fungi reduced the intensity of early blight by 34% and 23% respectively; and late blight levels by 53% and 70% respectively. The plant extracts reduced pest and disease damage on fruits by up to 40% and 65% respectively. Effectiveness of plant extracts and the antagonistic fungi compared favourably with that of the synthetic pesticides. The results showed that plant extracts and antagonistic fungi 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, Plant extracts, Antagonistic fungi, Tomato

1. Introduction

Tomato is one of the most important vegetables in the world and it's grown for its diverse use both for the fresh market and processing industries (Wachiraet al., 2014). In Kenya, tomatoes are grown commercially mainly by small scale farmers as a source of income. Tomato is affected by insect pests and pathogens which adversely affect its quality, quantity and profitability (Engindenizet al., 2013; Islam et al., 2013). Insect pests affect plants directly by feeding and indirectly by transmission of diseases (Sumitra et al., 2012). Farmers have relied on synthetic pesticides to manage pests and diseases in tomato (Mizubutiet al., 2007) such as late blight (*Phytophthorainfestans* Mont.de Bary) which is managed by a combination of protective and curative synthetic fungicides yet the losses in the field are devastating (Goufoet al., 2010).

There is growing concern on toxicity of the synthetic pesticides due to retention of residues in the food products (Stangarlinet al., 2011). In addition, the synthetic pesticides have negative effect on environment due to non-biodegradability, health hazards to the farmers, toxicity to non-target natural enemies and other beneficial organisms (Engindenizet al., 2013; Nainget al., 2013; Bhattacharjee and Dey, 2014). In some instances, farmers have been reported as not observing pre-harvest intervals (Srijita, 2015). Small scale farmers do not use protective gear while applying the chemicals and do not observe dilution instructions thus compromising their own safety (Goufoet al., 2008; Damalas and Koutrobous, 2015). The consumer markets have developed quality requirements with regard to maximum residue levels of pesticides in fresh vegetables (Pal and McSpadden, 2006; Wagnitz, 2014; Wafulaet al., 2014; Campos, 2014). These requirements have become more stringent especially for the amounts of chemical residues in fresh vegetables (European Commission, 2012).

Due to non-compliance with the market requirements, fresh vegetable produce has recently been denied access to lucrative markets and this has increased losses since the rejected produce has to be redirected to local markets which do not fetch good prices (The East African, 2015). Therefore, introduction of biopesticides in vegetable production systems will help reduce the risks associated with use of synthetic chemicals (Goufoet al., 2008).

Natural products are non-toxic, easily biodegradable, safe to non-target organisms and natural enemies and do not retain residues in the food products (Kimani, 2014).

2. Materials and Methods

2.1 Experimental siteand materials

On farm experiments were conducted from October 2015- April 2016on fields with a long history of tomato production. Fungal antagonists from a parallel study and active plant extracts from *in vitro* experiments were evaluated for their pest and disease management against synthetic pesticides, a commercial botanical and a commercial antagonist. The plant extracts evaluated were turmeric (*Curcuma longa*), garlic (*Allium sativum*), ginger (*Zingiberofficinale*) and lemon (*Citrus limon*) while the antagonistic fungi were two isolates of *Trichoderma* labelled as*Trichoderma*Sp1 and *Trichoderma*Sp2. Commercial synthetic fungicides were Isacop 80 WP® (Copper oxychloride- 50% metallic copper) and Ridomil Gold® (4% Metalaxyl-M and 64% Mancozeb) and an insecticide; Confidor SC 200® (0.125g/l Imidacloprid) while commercial plant extract and antagonist were Achook 0.15 EC® (*Azadirachtaindica*) and Trianum® (*Trichoderma harzianum*) respectively. The synthetic pesticides and commercial botanical and antagonist were standard checks while plots treated with water only were the negative controls. The treatments were laid out in randomized complete block design with three replicates and the experiments were conducted twice. Treatment application was initiated two weeks after transplanting tomato seedlings and thereafter the subsequent applications were done at seven day intervals. All the necessary agronomic practices such as fertilizer application, watering and weeding were carried out as required. Data was collected on population of insect pests, pest damage, disease distribution, incidence and severity and fruit yield.

2.2 Assessment of disease distribution, incidence and severity

Early blight and late blight were the most prevalent diseases and they were assessed on a weekly basis commencing three weeks after transplanting until the end of harvesting. 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. Disease incidence was assessed as the number of plants showing infection out of the total number of plants per plot and converted to percent, where 0 = no disease and 100% = all plants showing infection. The percent values of disease incidence were then converted into proportion, where 0 = no disease and 1 = all plants infected. Disease severity was assessed on ten plants randomly selected from the central rows within each plot on a 0-5 scale modified from Horsefall 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 as follows:

$$\text{Disease index} = \frac{\text{Distribution score} + \text{Incidence score} + \text{Severity score}}{\text{Maximum disease score (8)}} * 100$$

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.

2.3 Assessment of pest population and damage

Assessment of whiteflies (*Bemisiatabaci*) and leaf miner (*Tutaabsoluta*)commenced from the third week after transplanting until the end of harvesting as described by NICRA (2012). Ten plants were sampled from the central rows in each plot. The 10 plants were tagged and two leaflets were selected from each of the leaves on whichthe number of whitefly nymphs was counted on the underside and this was done during the early morning. Damage by *Tutaabsoluta* was assessed as the number of mines on all the leaves of the ten plants sampled. Assessment of pest population and damage was done on a weekly basis before the subsequent treatment application was done.

2.4 Assessment of fruit yield and quality

The weight of the harvested fruits were 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 overripe, 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 1-3 were the marketable portion while those with pest, disease and any other form of damage were the unmarketable portion.

2.5 Data collection and analysis

Data on populations of whitefly nymphs and leaf miner damage on leaves was collected on weekly basis as well as distribution, incidence and severity of early and late blight diseases. Yield categories were also collected and all the data was subjected to analysis of variance using Genstat® 15th Edition. Means were separated using Fischer's Protected LSD (Steel and Torrie, 1990).

3. Results

3.1 Effectiveness of plant extracts and antagonistic fungi in reducing populations of tomato pests

Plant extracts and antagonistic fungi significantly ($p \leq 0.05$) reduced the populations of whiteflies and *Tutaabsoluta* damage compared to the negative control (Table 1). The plant extracts were more effective in reducing populations of insects compared to the antagonists with extracts having reductions of up to 63% of whiteflies and 55% of *Tutaabsoluta*. Garlic (*Allium sativum*) was more effective in reducing the populations of *Tutaabsoluta* in both seasons. Lemon (*Citrus limon*) extracts were also effective in reducing populations of whiteflies especially in season two of experiments. Garlic extract was even more effective in reducing populations of whiteflies in season two in relation to the negative controls. The antagonists reduced the populations by up to 28% and 23% in whiteflies and *Tutaabsoluta* respectively (Table 1). There was no much difference in the effectiveness of the antagonistic fungi with the commercial brand Trianum®. Achook 0.15 EC®, a commercial botanical, significantly ($p \leq 0.05$) reduced the populations of the two insect pests compared to all the other treatments. This treatment was more effective on whiteflies especially during the second season. The synthetic pesticides reduced the populations of the two insect pests compared to the negative controls but with less effectiveness.

Table 1: Number of *Tutaabsoluta*mines and whitefly nymphs on tomato crop sprayed with plant extracts and antagonistic fungi.

Treatments	*Tutaabsoluta*		Whiteflies	
	Season 1	Season 2	Season 1	Season 2
Turmeric extract	24.3d	24.0cd	21.0cd	21.7d
Garlic extract	23.3d	22.7cd	20.7cd	16.7de
Ginger extract	24.3d	24.0cd	25.0c	22.3d
Lemon extract	27.0cd	24.0cd	21.0cd	18.0de
Trichoderma Sp 1	34.7b	34.0b	37.3b	30.3bc
Trichoderma Sp 2	35.0b	36.0b	36.3b	29.7c
Synthetics*	30.0c	26.0cd	45.3a	36.7b
Achook 0.15%EC®	18.3e	22.0d	17.7d	13.7de
Trianum T-22®	26.0d	27.7cd	37.7b	31.3bc
Control	42.3a	44.0a	48.7a	46.7a
LSD ($p \leq 0.05$)	3.8	5	5.1	6.5
CV (%)	7.7	10.2	9.5	14.1

Means followed by the same letter(s) within each column do not differ significantly at ($p \leq 0.05$).Synthetics* was a combination of Ridomil Gold®, Isacop 80 WP® and Confidor SC 200®

3.2 Efficacy of plant extracts and antagonistic fungi in management of early and late blight of tomato

Plant extracts and antagonistic fungi reduced intensity of early blight. There were no significant ($P \geq 0.05$) differences in season one while season two exhibited significant ($P \leq 0.05$) differences among the treatments (Figure 1). Turmeric (*Curcuma longa*) was significantly ($p \leq 0.05$) effective in reducing early blight in season two while among the antagonists, *Trichoderma* sp1 was effective in reducing early blight in the field in season two (Figure 1) relative to the synthetic pesticides and non-treated controls. Plant extracts and antagonistic fungi reduced late blight intensity (Figure 2) compared to the untreated control. One isolate of *Trichoderma* was the most effective followed by extracts of turmeric, ginger and garlic compared to the untreated controls (Figure 2).

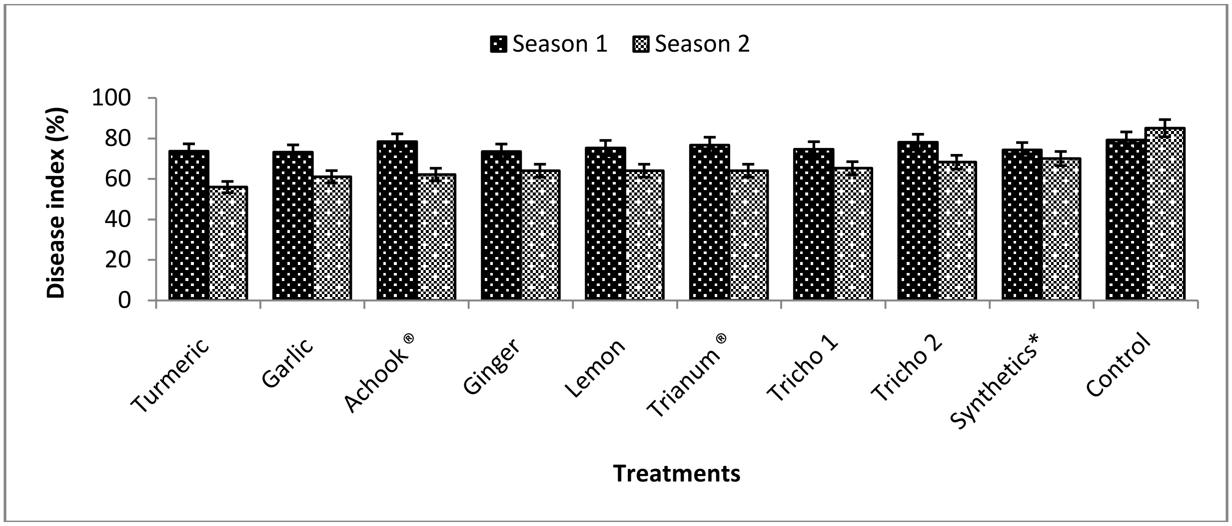

Figure 1: Percentage Disease Index for Early Blight Assessed from Tomatoes Sprayed with Plant Extracts and Antagonistic Fungi

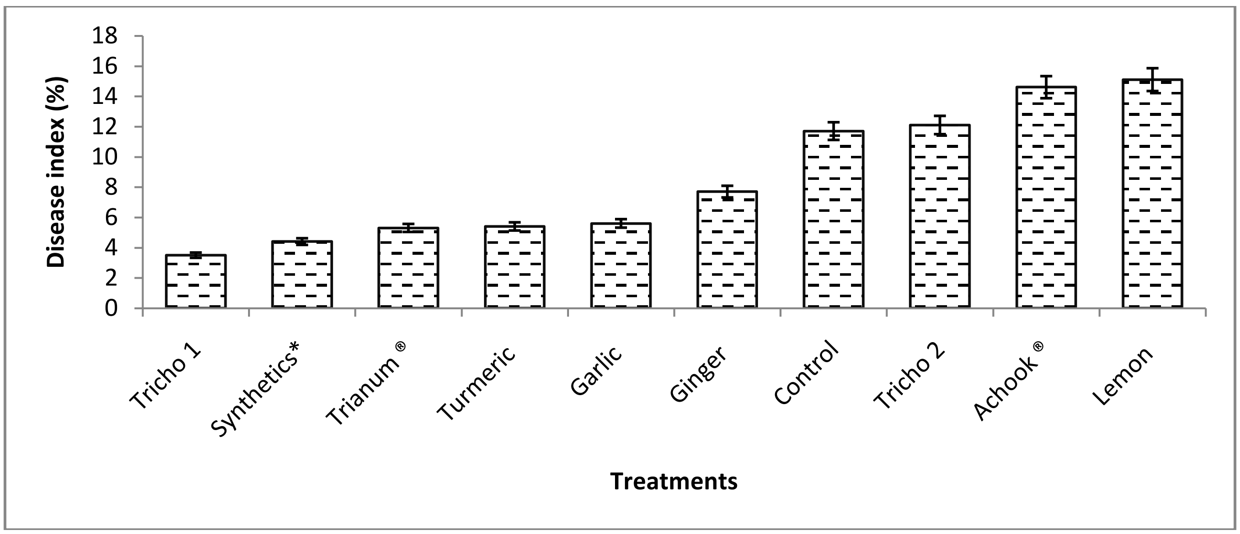

Figure 2: Percentage Disease Index for Late Blight Assessed from Tomatoes Sprayed with Plant Extracts and Antagonistic Fungi

3.3 Effectiveness of plant extracts and antagonistic fungi in improving tomato fruit yield and quality

There were significant differences ($p \leq 0.05$) in fruit yield of tomatoes treated with different plant extracts and antagonistic fungi. Yield from plants sprayed with Achook 0.15 EC®, a commercial botanical formulation, had the highest yield of grade 1 and 2 of marketable fruits while yield from plants treated with garlic extract had a significantly ($p \leq 0.05$) higher yield of grade 3 fruits. Plant extracts reduced pest infestations on fruit yield with more than 40% and disease infections by more than 65% (Table 2). Majority of the yield fell under the grade 3 categorywith the highest being from the garlic extracts.

Table 2: Fruit yield (Kg/ha) for different grades harvested from tomato crop treated with plant extracts and antagonistic fungi

Treatments	Grade 1	Grade 2	Grade 3	Non-marketable
Turmeric extract	180.0i	67.2i	574.0g	1466.0j
Garlic extract	406.3c	301.5c	2361.0a	1866.0h
Ginger extract	235.5g	129.6e	1244.0e	1710.0i
Lemon extract	207.4h	112.1ef	688.0f	2836.0c
Trichoderma Sp 1	472.0b	405.5b	1914.0c	2330.0e
Trichoderma Sp 2	301.1e	91.7fh	1917.0c	3652.0b
Synthetics*	345.8d	112.0efg	478.0g	2682.0d
Achook 0.15%EC®	512.0a	438.6a	1627.0d	2059.0h
Trianum T-22®	211.3h	89.3h	2164.0b	2179.0f
Control	261.1f	226.2d	1244.0e	3829.0a
LSD ($p \leq 0.05$)	17.6	19.6	109	118.9
CV (%)	3.3	5.8	4.5	2.9

Means followed by the same letter(s) within each column do not differ significantly at ($p \leq 0.05$). Synthetics* was a combination of Ridomil Gold®, Isacop 80 WP® and Confidor SC 200®

4 Discussion

Plant extracts and antagonistic fungi reduced the populations of *Tutaabsoluta* and whiteflies (*Bemisiatabaci*). These findings agree with those of Nwachukwu and Asawalam (2014) who reported that fresh garlic juice reduced populations of maize weevils while Damalas (2011) reported that turmeric has repellent property and it reduced populations of *Triboliumcastaneum, Sitophilus granaries* and *Rhyzoperthadominica.* Report by Sumitra et al.(2012) also showed that neem and ginger (*Zingiberofficinales*) effectively reduced populations of the leaf cutting beetle in mango. The antagonistic fungal sprays were not effective in pest management and this could be due to the source they were isolated from (Karimiet al., 2012), carrier material used (Gašić and Tanović, 2013) and the mode of action (Pal and McSpadden, 2006) since there is need for physical contact between the pest and the antagonist. The effectiveness of the plant extracts in reducing populations of insect pests in the field is attributed to the presence of volatile compounds which include saponins, alkaloids, tannins (Mizubutiet al., 2007), triterpenoids, sulphurous and polyacetate derivatives (Javaid and Rehman, 2011). These compounds could lead to blockage of the tracheal system of the insects which eventually leads to death (Mathew et al., 2014). They also affect the growth and development of insects by impairing their functioning (Damalas, 2011).

Both the extracts and the antagonistic fungi reduced the levels of early blight compared to the untreated control. The disease levels were however very high especially for early blight. The disease reduction potential was similar to that of the synthetic fungicides and these results agree with findings by Nashwa and Abo-Elyousr (2012) who evaluated neem, garlic, thorn apple and other plant extracts and found them effective in reducing the severity of early blight. Rodinoet al. (2014) also reported that extracts from rosemary (*Rosmarius officinalis*) and jimson weed (*Datura stramonium*) reduced the disease levels in the field. The reduced efficacy of plant extracts in the field has been attributed to low concentrations of the bioactive compounds found in those plants as reported by Mizubutiet al. (2007). The extraction method and the solvent system used have also been cited as a major determinant of the quality and yield of plant extracts (Odhiamboet al., 2009; Javaid and Rehman, 2011; Mahmoud et al., 2011; Bandoret al., 2013). However, Daboret al. (2007) reported that water extracts were the most effective compared to organic extracts which is contrary to our results and those of Mahmoud et al. (2011) who worked with ethyl acetate and reported organic extracts as the most effective. This is further confirmed by Reddy et al. (2012) who also reported ethanolic extracts to be the most effective. Bandoret al. (2013) reported that polar solvents produce better yield of extracts than non-polar solvents.

The reduction of late blight by antagonistic fungi and extracts could be due to isolation source of the antagonists (Karimiet al., 2012) as well as the medium of growth (Nainget al., 2013). This however disagrees with Chethanaet al. (2012) who reported average disease reduction by fungal antagonists and attributed it to prevailing environmental conditions. The antagonistic microbial species also differ in activity and mode of action (Srijita, 2015). The finding that the effectiveness of synthetic fungicides in reducing disease levels is comparable to that of plant extracts was also reported by Goufoet al. (2010) who reported plant extracts having similar results with synthetic fungicides against late blight in Cameroon. Nashwa (2011) reported that plant extracts from sweet basil, oleander, jimson weed and neem were effective in reducing early blight in the field but Ridomil Plus® was highly effective and similar findings were also reported by Ghorbani et al., (2005) who recounted copper oxychloride fungicide to be highly effective in managing late blight compared to the compost extracts. The latter further attributed the findings to the limited amounts of bioactive compounds in the extracts and their degradation with time.

In our findings, plant extracts and antagonistic fungi were effective in reducing late blight of tomatoes and compared well with the commercial fungicide formulations. These findings agree with studies by Islam et al. (2013) who worked with compost tea in an IPM program and reported that they reduced late blight severity effectively.

In the present study, there was increase in yield and in quality of tomato fruits from the extracts and antagonists. This differs with findings by Stangarlinet al., (2011) who reported that there were no yield differences in fruits harvested from plants sprayed with several plant extracts. The variation in activity of the plant extracts in reducing disease and enhancing fruit quality could be due to differences in the active chemical ingredients of the plants used, solvent extraction systems (Mizubutiet al., 2007; Bandoret al., 2013) and the fungal species evaluated (Nashwa and Abo-Elyousr, 2012). Some plant extracts and antagonistic microbes have some growth promotion effect which could increase the yield of the plants (Nainget al., 2013). Far from this, some biopesticides induce disease resistance systems of the plants which lead to healthy growth of the plants and thus better productivity (Nainget al., 2013).Quality improvement and increase in yield is as a result of reduced pests and diseases during growth and fruit development and this has been reported by several authors (Rizvi and Jaffar, 2015).Other plant extracts have been reported to have a growth promotion effect (Culver et al., 2012) resulting to increased tomato yield. Growth promotion effect has also been reported upon using microbial pesticides in managing pests and diseases (Rahman et al., 2014).

5 Conclusion

The study showed that plant extracts and antagonistic fungi are efficacious in reducing pest populations, disease levels and increase crop yield. Therefore, they can be incorporated in integrated pest and disease management programs, thereby reducing heavy application of synthetic pesticides which have negative effect on environment and leave harmful residues on produce. This would help meet the increasingly stringent quality requirements and hence improve access to prime markets, resulting in increased incomes for small scale tomato growers.

Acknowledgement

This project was funded by Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) Grant under the Competitive Grants System, Project No.RU/2014/GRG-096

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