

Full Length Research Paper

Control of whiteflies and aphids in tomato (*Solanum lycopersicum* L.) by fermented plant extracts of neem leaf and wild garlic

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Whitefly (*Bemisia tabaci*, Homoptera: Aleyrodidae) and aphid (Homoptera) on tomato (*Solanum lycopersicum* L.) are economically important insect pests that are difficult to manage due to their resistance to a wide range of chemical pesticides. Field experiments were conducted to assess the effects of fermented plant extracts of neem (*Azadirachta indica* A. Juss.) leaf and wild garlic (*Tulbaghia violacea*) on whitefly and aphid population. The population of both insect pests showed two different patterns with higher counts observed during summer than winter monitoring. During both seasons, numbers of whiteflies and aphids increased regardless of the treatment, but the numbers remained significantly lower within treated than untreated plots. The mixture of neem and wild garlic was more effective in reducing population densities of whitefly and aphid than either plant extract applied alone. In conclusion, results of this study suggested a synergistic effect of fermented plant extracts of neem and wild garlic as a bio-pesticide.

Key words: Aphid, bio-pesticide, fermented plant extract (FPE), *Solanum lycopersicum*, whitefly.

INTRODUCTION

Whitefly (*Bemisia tabaci*, Homoptera: Aleyrodidae) and aphid (*Myzus persicae*, Homoptera: Aphidae), obligate phloem-feeding insects, are two economically important pests affecting tomato (*Solanum lycopersicum*) production, both under protected and field conditions. Adults of these insects suck cell contents of infested plants and while feeding, excrete huge amounts of honeydew that eventually promotes development of sooty mould, which reduces the photosynthetic efficiency of the plant (Jazzar and Hammad, 2003). Severe infestation can lead to reduced plant vigour and growth, chlorosis,

uneven ripening or reduced crop yield (Hammad et al., 2000). Phloem-feeding insects, in addition to transmitting viruses, pose additional challenges as they may introduce enzymes into the phloem which may alter plant defense signaling (Kaloshian and Walling, 2005; Walling, 2008).

In South Africa, chemical insecticides are commonly used in attempt to control whitefly and aphid population densities (Nzanza et al., 2011). The presence of waxy shelters formed by the whiteflies, which resists penetration of chemicals and deters contact with the pest's immobile nymphal and pupal stages as well as the mobility and tremendous reproductive ability of aphids have contributed to reduced efficacy of chemical control (van Lenteren, 1990; Lowery et al., 1993; James, 2003; Yang et al., 2010). Additionally, due to frequent use of

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pesticides, these two insect pests have become resistant to an array of pesticides including pyrethroids, organophosphates, carbamates and insect growth regulators (Cahill et al., 1994; Horowitz et al., 1994; Jazzar and Hammad, 2003). Hence, considerable effort has been made towards the development of more environmentally sound technologies for management of these insect pests (Dimetry et al., 1996; Jazzar and Hammad, 2003).

Botanical insecticidal plants such as neem (*Azadirachta indica* A. Juss.) and wild garlic (*Tulbaghia violacea*), which are active against specific target species and biodegradable to non-toxic compounds, can be used in integrated management programmes (Markouk et al., 2000; Tare et al., 2004; Ateyyat et al., 2009). Neem extracts act as a strong antifeedant and repellent, delay and prevent moulting, reduce growth, development and oviposition; and can cause high mortality, in more than 200 insect species, including whiteflies and aphids (Coudriet et al., 1985; Prabhaker et al., 1989; Liu and Stansly, 1995; Mitchell et al., 2004; Kumar et al., 2005; Kumar et al., 2006).

Although all parts of neem tree possess botanical properties for pest control, the most potent results have been obtained with neem seed or oil, because of the high concentration of azadirachtin (Rovest and Deseo, 1991; Dimetry and Schmidt, 1992; Dimetry et al., 1996). However, with only few neem trees available in South Africa, the accessibility of seed materials was not easy. Another alternative has been to use neem leaf combined with wild garlic to enhance insecticidal effects as both plant materials have the potential to reduce insect pest population. However, the efficacy of neem leaf combined with wild garlic on phloem-feeding insects is not documented. The objective of the study was to investigate the efficacy of fermented plant extracts (FPE) of neem leaf and wild garlic on populations of whitefly and aphid in tomato production under field conditions.

MATERIALS AND METHODS

Experimental design, treatments and growth conditions

Field trials were conducted in winter and summer 2010 growing seasons at Bangani Farm, ZZ2-Bertie van Zyl, Mooketsi, South Africa (23° 29'14" S, 30° 09' 10" E, at 702 m above sea level). Mean day/night minimum temperatures ranged from 23°C/15°C to 21°C/15°C, whereas mean day/night maximum temperatures ranged from 28°C/23°C to 29°C/25°C. Treatments consisted of neem leaf fermented plant extract (Neem-FPE), wild garlic fermented plant extract (Garlic-FPE), mixture of neem leaf and wild garlic plant extracts (GarNeem-FPE) and untreated plots. Tomato seedlings raised in ZZ2 nursey were transplanted onto 30-cm high raised beds with a spacing of 15 cm within rows. Each plot consisted of two adjacent rows 10 m long and 1.8 m wide. Treatments were arranged in a randomized complete block design, with four replicates. Each block was separated with 2.5 m border

between blocks. Cultural practices, irrigation and fertilisation were done according to ZZ2's standard operating procedures (Nzanza et al., 2011).

Preparation of fermented plant extracts

The fermented plant extracts were prepared following the method of Kyan et al. (1999). Approximately 2 kg of neem fresh leaves were collected from healthy mature trees and chopped into pieces. For wild garlic, the whole plant was used. Chopped plant materials were placed in a 20 L bucket and filled with 14 L water, 420 ml of molasses and 420 ml of effective microorganisms (EM). The bucket was tightly closed and the materials allowed to undergo an anaerobic fermentation for approximately 14 days. At the end of the process, when pH had dropped to below 3.7, the solution was passed through a 2 mm cloth and the resultant solution diluted in water (0.5%). Treatments were initiated two weeks after transplanting for five successive weeks using a knapsack sprayer at seven day interval.

Insect monitoring and data analysis

Scouting started two weeks after planting and was carried out for five successive weeks. Insect samples were collected weekly between 7 h 30 and 9 h 30. *In-situ* counts of whitefly adults and aphids were performed on ten randomly selected plants by gently turning the leaf and counting the number of insect pests starting from the top, middle and bottom section of the plant. The mean value of insect pest per leaf was calculated. Data were subjected to analysis of variance using SAS (SAS Institute Inc., Cary, NC, USA. (2002-2003). Mean separation was achieved using Fisher's least significant difference test. Unless stated otherwise, treatments discussed were different at 5% level of probability.

RESULTS

Effect of fermented plant extracts (FPE) on whitefly adults

During both seasons, all FPE-treated plots had lower whitefly population density than those of untreated plots. Except for the first sampling interval, the lowest counts of whitefly adults were found in GarNeem-FPE, followed by Neem-FPE and Garlic-FPE during both seasons. In both seasons, there were no significant differences among the FPE-treated plots in the first three weeks. Also, there were no significant differences between GarNeem-FPE and Neem-FPE in both seasons, at different sampling, except for the last summer sampling. In contrast, under GarNeem-FPE, population density of whitefly adults was significantly different to that under Garlic-FPE onward from the fourth sampling interval during both seasons. Regardless of the treatment applied, the number of whitefly adults increased as the season progressed. In untreated plots, the number of whitefly adults increased from 5.75 after the first treatment application to 18.35 (219%), after the fifth application in winter, and from

Table 1. Average number of whitefly adults as affected by fermented plant extracts of garlic, neem and garlic + neem (CarNeem) at five sampling intervals.

Application time (Days)	Treatment			
	Garlic-FPE	Neem-FPE	GarNeem-FPE	Control
Winter 2010				
7	3.87 ^{ab} ± 0.47	2.75 ^b ± 1.25	3.30 ^b ± 0.45	5.75 ^a ± 1.67
14	4.67 ^b ± 0.57	3.6 ^b ± 1.80	3.05 ^b ± 0.82	12.65 ^b ± 2.11
21	6.82 ^b ± 0.53	5.35 ^b ± 1.20	4.10 ^b ± 0.80	10.85 ^a ± 2.81
28	7.80 ^b ± 0.66	5.22 ^{bc} ± 0.74	4.70 ^c ± 0.62	13.97 ^a ± 3.43
35	12.72 ^b ± 1.67	10.92 ^{bc} ± 2.47	8.17 ^c ± 1.15	18.35 ^a ± 4.06
Summer 2010				
7	7.77 ^b ± 3.19	6.07 ^b ± 1.82	6.70 ^b ± 1.19	15.95 ^a ± 4.20
14	15.47 ^b ± 1.73	15.02 ^b ± 5.25	9.52 ^b ± 5.62	28.35 ^a ± 4.95
21	18.72 ^b ± 5.52	18.30 ^b ± 2.06	11.75 ^b ± 3.01	35.32 ^a ± 4.93
28	± 23.92 ^b ± 3.35	± 20.17 ^{bc} ± 5.05	± 15.45 ^c ± 1.69	± 46.07 ^a ± 7.79
35	± 35.80 ^b ± 7.41	± 31.50 ^b ± 2.17	± 16.97 ^c ± 4.70	± 60.67 ^a ± 8.12

Row means with the same letter were not different at the probability of 5% according to Fisher's least significant test.

15.95 to 60.67 (280%) in summer, whereas in the GarNeem-FPE plot, the number increased from 3.30 to 8.17 (148%) and from 6.70 to 16.97 (153%), in winter and summer, respectively (Table 1).

Effect of fermented plant extracts (FPE) on whitefly nymphs

During winter, there were no significant differences in population densities of whitefly nymphs between the untreated and FPE-treated plots at 21 days after treatment. However, at 28 days after treatment, the population density of whitefly nymphs was significantly lower under Neem-FPE when compared to the untreated plots. No differences were found among the FPE-treated plots. In summer, the number of whitefly nymphs under FPE-treated plants was not different to that on untreated plots only at 7 days after treatment, whereas at 21 and 35 days, GarNeem-FPE had significantly reduced population density of whitefly nymphs when compared to the untreated control.

At 28 days, all the FPE-treated plots had significantly reduced numbers of whitefly nymphs. As the season progressed, the number of whitefly nymphs increased regardless of the treatment application. In winter, relative to the 7 day initial treatment, the number of whitefly nymphs in Garlic-FPE, Neem-FPE, GarNeem-FPE and control increased by 350, 341, 469 and 368%, respectively, whereas in summer the relative increments were 213, 213, 208 and 322%, respectively (Table 2).

Effect of fermented plant extracts (FPE) on aphids

In winter, all the FPE-treated plots had significantly lower aphid counts when compared to the untreated plot. Aphid counts were the lower in GarNeem-FPE, Neem-FPE and Garlic-FPE throughout both trials. In summer, at 7 day interval, population density of aphids was significantly lower in the GarNeem-FPE when compared to untreated plot. From 14 day sampling interval, all FPE-treated plots had significantly lower aphid population counts when compared to the control plots. There were no significant differences among the FPE-treated plots, except at the last sampling where GarNeem-FPE had a significantly lower aphid counts when compared to Neem-FPE. As the season progressed, the number of aphids increased regardless of the treatment application. The number of aphids in Garlic-FPE, Neem-FPE, GarNeem-FPE and control ranged from 0.1 to 5.12, 0.2 to 4.92, 0.05 to 4.32, and 0.77 to 11.07, respectively, in winter and from 0.47 to 6.67, 0.55 to 9.42, and 0.25 to 6.30, and 1.02 to 17.55, respectively, in summer (Table 3).

DISCUSSION

Field experiments with tomato showed that fermented plant extracts of neem and wild garlic, alone or in combination, have insecticidal properties to maintain lower population densities of whitefly and aphid. All parts of neem contain bitter compounds (Van der Nat et al., 1991; Chawla et al., 1995) that often have an antifeedant

Table 2. Average number of whitefly nymphs as affected by fermented plant extracts of garlic, neem and garlic + neem (GarNeem) at five sampling intervals.

Application time (Days)	Treatment			
	Garlic-FPE	Neem-FPE	GarNeem-FPE	Control
Winter 2010				
7	1.35 ^a ± 0.47	1.27 ^a ± 0.20	1.05 ^a ± 0.10	1.50 ^a ± 0.57
14	3.37 ^{ab} ± 0.78	2.85 ^b ± 0.43	2.57 ^b ± 1.10	4.05 ^a ± 1.08
21	3.52 ^a ± 0.79	3.92 ^a ± 0.22	3.45 ^a ± 0.65	3.60 ^a ± 0.53
28	5.60 ^{ab} ± 0.90	4.52 ^b ± 0.62	4.87 ^{ab} ± 0.41	6.10 ^a ± 1.23
35	6.07 ^{ab} ± 1.00	5.60 ^b ± 0.41	5.97 ^{ab} ± 0.25	7.02 ^a ± 0.78
Summer 2010				
7	4.72 ^a ± 0.48	4.57 ^a ± 0.95	4.25 ^a ± 0.44	4.27 ^a ± 0.62
14	7.62 ^a ± 1.55	6.60 ^a ± 0.80	5.72 ^a ± 1.20	6.77 ^a ± 1.29
21	8.45 ^{ab} ± 0.97	8.37 ^{ab} ± 1.10	7.02 ^b ± 0.85	9.32 ^a ± 1.95
28	6.80 ^b ± 0.63	8.32 ^b ± 2.14	7.97 ^b ± 2.14	11.37 ^a ± 0.94
35	14.75 ^{ab} ± 2.21	14.30 ^{ab} ± 3.00	13.07 ^b ± 0.86	18a ± 2.82

Row means with the same letter were not different at the probability of 5% according to Fisher's least significant test.

Table 3. Average number of aphids as affected by fermented plant extracts of garlic, neem and garlic + neem (GarNeem) at five sampling intervals.

Application time (Days)	Treatment			
	Garlic-FPE	Neem-FPE	GarNeem-FPE	Control
Winter 2010				
7	0.10 ^b ± 0.08	0.20 ^b ± 0.14	0.05 ^b ± 0.10	0.77 ^a ± 0.44
14	1.10 ^b ± 0.31	0.82 ^b ± 0.32	0.60 ^b ± 0.37	1.85 ^a ± 0.38
21	1.40 ^b ± 0.57	1.27 ^b ± 0.61	1.02 ^b ± 0.36	4.02 ^a ± 0.40
28	2.27 ^b ± 0.82	2.42 ^b ± 0.53	1.27 ^b ± 0.65	6.92 ^a ± 1.76
35	5.12 ^b ± 1.15	4.92 ^b ± 1.98	4.32 ^b ± 1.05	11.07 ^a ± 2.91
Summer 2010				
7	0.47 ± 0.38	0.55 ± 0.36	0.25 ± 0.20	1.02 ± 0.63
14	1.17 ± 0.55	0.97 ± 0.46	0.90 ± 0.39	3.10 ± 1.14
21	1.42 ± 0.57	1.67 ± 1.04	1.65 ± 0.62	2.97 ± 0.61
28	3.37 ± 0.88	3.10 ± 1.11	3.45 ± 1.43	7.65 ± 1.51
35	6.67 ± 1.82	9.42 ± 1.35	6.30 ± 1.78	17.55 ± 3.29

Row means with the same letter were not different at the probability of 5% according to Fisher's least significant test.

effect and can interfere with hormonal processes in insects (Schmutterer, 1990; Ascher, 1993; Boeke et al., 2004). Similarly, wild garlic bulbs possess chemical compounds such as sacrid volatilis oil and sulpho-oxides derived from allicin, responsible for the antifeedant, repellent and toxicant properties against various pests (Vijayalakshmi et al., 1996; Dhanalakshmi, 2006). However, the fact that the population densities of whitefly and aphid increased over time throughout the season

regardless of the treatment applied, suggested that fermented plant extracts of neem and wild garlic could possibly have had a repellent effect on the two insects. Differences in the numbers of whiteflies and aphids in winter and summer were possibly due to seasonal variations.

Neem results in this study confirmed those of this material which reduced both the population densities of whitefly and aphid on cabbage (Basedow et al., 2002;

Zaki, 2008). Jazzar and Hammad (2003) noted that aqueous leaves and fruit extracts from *Melia azedarach* L. (Meliaceae), a close relative of neem, produced greater mortality of whiteflies than on control plants. Similarly, leaf extracts of neem previously resulted into significant mortality of bean aphids (Bahar et al., 2000; Saikia et al., 2000). Also, extracts from the Alliaceae family were shown to reduce population densities of sucking insects. For instance, Flint et al. (1995) noted that garlic extracts reduced population density of whitefly adults in cotton. Garlic fermented plant extract reduced thrips in onion (Helondo, 2004; Zimmermann and Kamukuenjandje, 2008).

In our trial, although Garlic-FPE consistently reduced the population densities of aphid and whitefly, this was less effective than the Neem-FPE. The observation was in agreement with Bahar et al. (2000) who observed a reduction on population density of aphid in yard-long beans, with inconsistent results when compared to neem leaf extract. Chitra et al. (1997) noted that garlic extract was least effective in controlling population density of aphid than neem-based products. Ravikumar (2004) concluded that sole application of garlic extract was less effective in reducing the population of sucking insects.

In our trial the mixture of neem with wild garlic was more effective in suppressing the population density of whitefly adults compared to either extract applied alone, suggesting a synergistic effect of these two plant extracts. Similar results were obtained with Lakshman (2001) who found that garlic bulb extract in combination with neem leaves and other extracts effectively reduced aphids and whiteflies infesting several crops (Pareet, 2006). Most of the successfully observed results with sucking insects have been obtained with neem seeds or oil with little evidence in aqueous or fermented leaves extract.

In conclusion, results of this study showed that mixture of neem and garlic fermented plant extracts were more effective in suppressing population densities of aphid and whitefly, than either plant extract alone. Generally, the number of aphids and whiteflies increased as the season progressed suggesting that fermented plant extracts have repellent effects as opposed to other mechanisms such as antifeedant activities. However, further studies are needed to better understand the mode of action of fermented plant extracts in GarNeem.

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