Susceptibility of geographically isolated populations of the Tomato red spider mite (*Tetranychus evansi* Baker & Pritchard) to commonly used acaricides on tomato crops in Kenya

F.J. Toroitich,1,2 M. Knapp,3 J.H. Nderitu,1 F.M. Olubayo,1 M. Obonyo4

1Department of Plant Sciences and Crop Protection, Faculty of Agriculture, University of Nairobi, Nairobi, Kenya; 2African Insect Science for Food and Health (ICIPE), Nairobi, Kenya; 3Koppert Biological Systems, Postbus, Berkel en Rodenrijs, The Netherlands; 4Department of Biochemistry, Egerton University, Njoro, Kenya

Abstract

Farmers in Kenya continue to raise concerns of difficulty in managing *Tetranychus evansi*, the most widespread pest species of tomato applying the most commonly used acaricides. This invasive pest species is not only found in Kenya, but in Eastern and Southern Africa, as well as parts of Europe and Asia. In the current study, populations of *T. evansi* were collected from farms in the four major tomato-growing areas of Kenya (Loitokitok, Kibwezi, Athi-River and Subukia) and their susceptibility compared to a laboratory culture (ICIPE) that had been maintained for three years without exposure to acaricides. Susceptibility of *T. evansi* eggs and adults (contact and residual) to Brigade (bifentrin), Dimethoate (dimethoate), Karate (lambda-cyhalothrin), Kelthane (dicrof), Omite (propargite) and Polytrin (profenofos+cypermethrin) was tested in the laboratory using respective manufacturer’s recommended concentrations. Dimethoate resulted in variable ovisual mortality while Kelthane, Brigade, Karate, Omite and Polytrin had high mortality across all populations. Similarly, adult contact and residual mortality was lower than that of the other chemicals when exposed to Dimethoate regardless of the location. Furthermore, it also had no residual effect on the mites from ICIPE and Kibwezi. On the other hand, Kelthane was most lethal against the mites from all locations followed by Brigade and Polytrin in that order. Omite caused significantly lower mortality on mites from Subukia while Karate produced variable effects on mites from Kilwezi, Loitokitok and Subukia. The implications of these findings are further discussed.

Introduction

The tomato red spider mite, *Tetranychus evansi* Baker & Pritchard, is an important invasive pest species of solanaceous plants not only in Kenya and other parts of Africa (Varela et al., 2003; Knapp et al., 2003), but in parts of Europe (Ferreira & Carmona, 1995; Ferragut & Escudero, 1999; Migeon, 2005; Castagnoli et al., 2006; Tsagkarakou et al., 2007) as well as Asia (Ho et al., 2004; Gotoh et al., 2009). It is believed to have originated from South America (Moutia, 1958) and was first reported in continental Africa in 1979 on tobacco in Zimbabwe (Blair, 1983) from where it spread to other parts of the continent. In Kenya, *T. evansi* was initially reported in 2001 on tomato (Knapp et al., 2003) and has since been reported in several other solanaceous plants in many parts of the country (Toroitich et al., 2009). Besides its invasive nature, recent reports indicate that *T. evansi* may be displacing native spider mite species hence posing new pest management challenges (Ferragut et al., 2013).

While there are efforts to control *T. evansi* using cultural practices (Saunyama & Knapp, 2003), application of synthetic acaricides remains the method of choice in Kenya. This, however, is faced by the risk of resistance development among pest populations due to prolonged exposure (Cranham & Helle, 1985; Blair, 1989; Tsagkarakou et al., 2002; Nyoni et al., 2011) or even poor application techniques.
(Sibanda et al., 2000). It has been observed that farmers in Africa frequently apply lower than recommended tank concentrations of chemicals and even use sprayers with inappropriate or worn-out nozzles and do not spray carefully enough leading to poor crop coverage (Sibanda et al., 2000; Saunyama & Knapp, 2003). As a result, farmers frequently complain of ineffective acaricides, as the pest populations appear to resurge immediately after application.

It was hypothesised that geographically isolated T. evansi populations were likely to differ in their susceptibility to acaricides depending on their history of chemical exposure. A prerequisite was to conduct farmer interviews to establish the predominant chemical(s) used in each region and thereafter test the susceptibility of T. evansi populations to the reported chemicals at the respective manufacturer’s recommended concentrations.

**Materials and methods**

The chemical compounds (and respective trade names) commonly used for Red Spider mite control in tomato production in Kenya are listed below (Table 1).

**Spider mite collection**

Spider mites were collected from tomato fields in Athi-River Division (Machakos County), Kibwezi Division in Makueni County, Loitoktok Division in Kajiado County and Subukia Division in Nakuru County, Kenya.

Twenty to thirty infested tomato leaves were collected from each farm where mites were observed. Mites from six farms in Athi-River, four in Loitoktok, two in Kibwezi and six in Subukia were collected between April and July 2004. Leaf samples were put in paper bags, then placed in a cool box and transported to ICIPE laboratory for examination. In the laboratory, at least 20 males from each of the sampled sites were mounted for identification. At the same time, 60-100 live females were picked from the infested leaves collected per site (no more than one spider mite was taken from a single leaf) for rearing.

The T. evansi populations from Athi River, Kibwezi, Loitoktok and Subukia were reared in water isolation cages designed after those described by Dennehy and Granett (1982). Potted tomato plants (variety Cal-J) were placed on top (bottom part) of inverted pots inside a Basin (90 cm diameter) half-filled with water. A clear-sided Perspex cage (30 × 30 × 90 cm) whose topside was covered with fine polyester lining (for ventilation) was placed over the potted plants to prevent escape of mites (Figure 1). The spider mites were reared at same conditions of temperature (25±2°C), relative humidity (50-80%) (RH) and photoperiod (12L:12D) h in the laboratory. An ICIPE laboratory culture previously collected from Mwea (Kirinyaga County) and maintained on tomatoes without exposure to acaricides for three years was used for comparison.

Commercial acaricides were used in the experiments as follows: Polytrin 440 EC (profenofos Q 400 g/L+cypermethrin 40) (Syngenta Crop Protection, Switzerland), Brigade 025EC (bifenthrin 25 g/L) (FMC Corporation, USA), Karate 1.75 EC (lambda-cyhalothrin 17.5 g/L (Syngenta Crop Protection), Dimethoate 40% EC (dimethoate 400 g/L) (Eastchem, China), Omite 57 EC (propargite 57%, Crompton Corporation, USA) and Kelthane EC (dicofol 18.5%) (Rohm and Haas Company, USA).

**Ovicidal tests**

For each pesticide, twenty T. evansi females from respective colonies were transferred onto tomato leaf discs (25 mm diameter) placed lower side up on moist cotton wool in Petri dishes (9 cm diameter). The Petri dishes were placed in rectangular plastic boxes (30 × 50 × 10 cm) and maintained at 25±2°C in an incubator. The females were allowed 24 h oviposition time after which they were removed and the number of eggs adjusted to 20. Pesticide solutions were prepared following respective manufacturer’s recommended rates as follows: Polytrin (1.5 L/ha), Brigade (2.5 L/ha), Karate (2.5 L/ha), Dimethoate (1 L/ha), Omite (1 L/ha) and Kelthane (2.5 L/ha). In addition, Aquawet (nonylphenol ethoxylate, Osho Chemicals, Kenya) was added as a sticker to all the chemical solutions and water at 1 L/ha.

The leaf discs containing T. evansi eggs from respective locations were dipped in pesticide solutions for five seconds and placed lower side up in plastic Petri dishes containing moist cotton wool. The num-

---

**Table 1. Chemicals commonly used for Red Spider mite control in tomato production in Kenya (ICIPE, 2003, unpublished survey data).**

<table>
<thead>
<tr>
<th>Compound</th>
<th>Trade name</th>
<th>Class</th>
<th>% of farmers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dicofol</td>
<td>Kelthane</td>
<td>A</td>
<td>25.8</td>
</tr>
<tr>
<td>Lambda-cyhalothrin</td>
<td>Karate</td>
<td>I/A</td>
<td>24.7</td>
</tr>
<tr>
<td>Dimethoate</td>
<td>Dimethoate</td>
<td>I/A</td>
<td>22.7</td>
</tr>
<tr>
<td>Cypermethrin+profenofos</td>
<td>Polytrin</td>
<td>I/A</td>
<td>19.6</td>
</tr>
<tr>
<td>Bifenthrin</td>
<td>Brigade</td>
<td>I/A</td>
<td>13.4</td>
</tr>
<tr>
<td>Propargite</td>
<td>Omite</td>
<td>A</td>
<td>10.3</td>
</tr>
</tbody>
</table>

A, acaricide; I, insecticide.
ber of eggs was checked to ensure none were lost in the dipping process. The Petri dishes were placed on a wire mesh inside plastic boxes (30x50x10 cm) and maintained under the same conditions earlier described. Water and Aquawet sticker was used as the negative control. The experiments were arranged in a completely randomized design and replicated six times for all treatments.

The leaves were examined the first time after four days and subsequently daily for another five days for larval emergence. Egg mortality was determined by comparing the number of unhatched eggs with the initial number of post treatment eggs (Agnello et al., 1994).

**Adulcidal tests**

The bioassays employed were similar to those described by Kabir et al. (1993) with some modifications as outlined below.

**Modified leaf disc direct method**

Twenty, day-old adult *T. evansi* females from the colonies that had been reared for six weeks from the time of collection were transferred onto the lower side of tomato leaf discs (25 mm diameter). The leaf discs containing mites were carefully dipped in the acaricide solutions for 5 seconds before being placed lower side up in plastic Petri dishes containing moist cotton wool. The Petri dishes were left on the bench for one hour to allow the leaves to dry then introduced into plastic boxes (mentioned above) and maintained in an incubator as already described. Similarly, the experiments were arranged in a completely randomized design and replicated six times.

After 24 h the mites were observed and scored as dead, alive or escaped for those which were trapped in the cotton barrier (Agnello et al., 1994). Mites were considered dead when they did not react to gentle prodding with a camel hairbrush. Escaped mites were excluded from the analyses.

**Leaf disc residue – dipping method**

Leaf disc residue – dipping method differs from leaf disc direct method (LDD) slightly in that the leaf discs were first dipped in the acaricide solutions for five seconds, then placed in Petri dishes and allowed to dry at room temperature for about 30 min. Similar to the LDD, spider mites were transferred onto the discs and observed after 24 h and scored as dead, alive or escaped. Escaped mites were excluded from the analyses.

**Data analysis**

Data on egg and adult mortalities were arcsine square root transformed then subjected to one-way analysis of variance (Proc GLM) and means separated by Student-Newman-Keuls test (SAS 9.1, 1990). However, data presented in the tables are actual percent mortalities. In addition, only for ovicidal tests, control mortality was corrected using Abbott’s formula (Abbott, 1925) while for adult mortalities actual uncorrected figures were used.

### Results

**Acaricides used for spider mites control**

In Loitoktok, three of four sampled farmers used Dimethoate while the remaining one used Polytrin. On the other hand, in Subukia three farmers used Polytrin, two-used Tata Alpha (alpha-cypermethrin) and the remaining one used Karate. In Kibwezi, both farmers used Karate but one alternated its use with Brigade. In Athi River, four of six farmers used Karate while each of the remaining ones used Dimethoate and Kelthane.

The farmers in Subukia complained of spider mites being a persistent problem in the area and explained their choice of Polytrin as the most effective chemical against insects and spider mites. In Kibwezi and Athi River, spider mites were not cited as a major problem, although the farmers conventionally applied acaricides albeit infrequently. Similarly, most farmers in Loitoktok had scanty knowledge of spider mites hence they were not ranked as important pest of tomato. However, the farmers routinely applied Dimethoate against all pest infestations.

**Ovicidal tests**

Compared to the other chemicals, Dimethoate resulted in variable ovicidal mortality among the tested *T. evansi* populations. Significantly lower mortality was observed in Subukia and Kibwezi populations while Loitoktok, ICIPE and Athi River ones had minimal susceptibility comparable to the negative control. On the other hand, treatments by Kelthane, Brigade, Karate, Omite and Polytrin resulted in significantly (<0.0001) high (about 100%) egg mortality in all populations (Table 2).

**Adulcidal tests: contact mortality**

(leaf disc direct method)

In a trend similar to the ovicidal test, mortality of adult mites was significantly lower (*P = 0.0099*) than the other chemicals when exposed to Dimethoate regardless of the location (Table 3). However, with the exception of Athi River where mortality did not differ significantly from the negative control, in the other locations some differences were reported. Significant differences (*P = 0.0202*) were observed among populations when Karate was applied as follows: highest mortality attained was with ICIPE and Kibwezi mites at 70% and as low as 43% for those from Loitoktok. This is much lower than the response to

### Table 2. Mortality of spider mite eggs following treatment by various acaricides (N=6 in all cases).

<table>
<thead>
<tr>
<th>Treatment/Location</th>
<th>Athi River</th>
<th>ICIPE</th>
<th>Kibwezi</th>
<th>Loitoktok</th>
<th>Subukia</th>
<th>P-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brigade</td>
<td>100.0±0.0a</td>
<td>100.0±0.0a</td>
<td>100.0±0.0a</td>
<td>100.0±0.0b</td>
<td>100.0±0.0a</td>
<td>-</td>
</tr>
<tr>
<td>Control</td>
<td>0.0±0.0**a</td>
<td>0.0±0.0**a</td>
<td>0.0±0.0**a</td>
<td>0.0±0.0**a</td>
<td>0.0±0.0**a</td>
<td>-</td>
</tr>
<tr>
<td>Dimethoate</td>
<td>0.0±0.0**a</td>
<td>8.7±3.4**c</td>
<td>33.3±7.6**b</td>
<td>13.0±4.3**c</td>
<td>54.0±10.9**a</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Karate</td>
<td>98.8±1.17**a</td>
<td>100.0±0.0a</td>
<td>96.7±2.1**a</td>
<td>99.0±1.0**a</td>
<td>93.5±5.5**a</td>
<td>0.0084</td>
</tr>
<tr>
<td>Kelthane</td>
<td>100.0±0.0a</td>
<td>100.0±0.0a</td>
<td>100.0±0.0a</td>
<td>100.0±0.0a</td>
<td>100.0±0.0a</td>
<td>-</td>
</tr>
<tr>
<td>Omite</td>
<td>100.0±0.0a</td>
<td>100.0±0.0a</td>
<td>100.0±0.0a</td>
<td>100.0±0.0a</td>
<td>100.0±0.0a</td>
<td>-</td>
</tr>
<tr>
<td>Polytrin</td>
<td>100.0±0.0a</td>
<td>100.0±0.0a</td>
<td>100.0±0.0a</td>
<td>100.0±0.0a</td>
<td>100.0±0.0a</td>
<td>-</td>
</tr>
<tr>
<td>P-values</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>-</td>
</tr>
</tbody>
</table>

**Means±SE down the columns are significantly different (*P<0.05*) (Analysis of variance (ANOVA) and Student-Newman-Keuls (SNK)); **Means±SE followed by different letters across the rows are significantly different (*P<0.05*) (ANOVA and SNK).
Omite, Brigade, Polytrin and Kelthane which caused nearly 100% mortality among all spider mite populations.

Residual effect of the acaricides on *T. evansi* (leaf disc residue – dipping method)

The residual effect of various acaricides followed the pattern observed with contact mortality (Table 4). Compared to the other chemicals Dimethoate had the least significant residual effect on *T. evansi* adults from Subukia, Loitoktok and Athi River while it had no effect on those from ICPE and Kibwezi. On the other hand, Kelthane was most lethal against the mites from all locations followed by Brigade and Polytrin in that order. Omite caused significantly lower (P=0.0363) mortality on mites from Subukia while Karate produced variable effects on mites from Kibwezi, Loitoktok and Subukia.

**Discussion and conclusions**

Farmers in the major tomato producing areas of Kenya appear to prefer Omite, Polytrin, Dimethoate and Karate as acaricides. It is evident that most of these acaricides are still effective against *T. evansi* both as ovicides and adulticides. The current study shows that Kelthane (dichlofolf) was the most effective acaricide. This corroborates earlier findings that reported high efficacy of dichlofolf against *Tetranychus urticae* Koch (Wilson et al., 1995). Dicofol, cyhexatin, fenbutatin oxide and prodigite are among the few selective acaricides that have been successful-.

Table 3. Mortality of adult mites due to contact with various acaricides (N=6 in all cases).

<table>
<thead>
<tr>
<th>Treatment/Location</th>
<th>Athi River</th>
<th>ICPE</th>
<th>Kibwezi</th>
<th>Loitoktok</th>
<th>Subukia</th>
<th>P-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brigade</td>
<td>100±0*a</td>
<td>100±0*a</td>
<td>100±0*a</td>
<td>98.8±0.9*a</td>
<td>100±0*a</td>
<td>0.4261</td>
</tr>
<tr>
<td>Control</td>
<td>4.46±0.05**a</td>
<td>0.0±0**a</td>
<td>7.01±0.05**a</td>
<td>2.55±0.04**a</td>
<td>3.38±0.05**a</td>
<td>0.4404</td>
</tr>
<tr>
<td>Dimethoate</td>
<td>11.46±0.09**a</td>
<td>7.01±0.05**a</td>
<td>48.4±0.19**a</td>
<td>27.4±0.14**a</td>
<td>27.39±0.09**a</td>
<td>0.0099</td>
</tr>
<tr>
<td>Karate</td>
<td>56.69±0.08**a</td>
<td>71.34±0.05**a</td>
<td>70.1±0.11**a</td>
<td>43.95±0.07**a</td>
<td>63.06±0.12**ab</td>
<td>0.0202</td>
</tr>
<tr>
<td>Kelthane</td>
<td>100±0*a</td>
<td>100±0*a</td>
<td>100±0*a</td>
<td>100±0*a</td>
<td>100±0*a</td>
<td>-</td>
</tr>
<tr>
<td>Omite</td>
<td>100±0*a</td>
<td>97.45±0.04*a</td>
<td>100±0*a</td>
<td>100±0*a</td>
<td>100±0*a</td>
<td>0.4261</td>
</tr>
<tr>
<td>Polytrin</td>
<td>97.45±0.04*a</td>
<td>100±0*a</td>
<td>100±0*a</td>
<td>100±0*a</td>
<td>100±0*a</td>
<td>0.4261</td>
</tr>
<tr>
<td>P-values</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

**Means±SE down the columns are significantly different (P=0.05) [Analysis of variance (ANOVA) and Student-Newman-Keuls (SNK)].**

Table 4. Mortality of adult mites due to residual effect of various acaricides (N=6 in all cases).

<table>
<thead>
<tr>
<th>Treatment/Location</th>
<th>Athi River</th>
<th>ICPE</th>
<th>Kibwezi</th>
<th>Loitoktok</th>
<th>Subukia</th>
<th>P-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brigade</td>
<td>96.82±0.05*a</td>
<td>100.0±0*a</td>
<td>70.0±0.30*a</td>
<td>92.99±0.07*a</td>
<td>89.17±0.11**a</td>
<td>0.2202</td>
</tr>
<tr>
<td>Control</td>
<td>7.01±0.05*a</td>
<td>0.0±0**a</td>
<td>0.0±0**a</td>
<td>5.73±0.06**a</td>
<td>5.73±0.06**a</td>
<td>0.2256</td>
</tr>
<tr>
<td>Dimethoate</td>
<td>8.28±0.06*a</td>
<td>0.0±0**a</td>
<td>0.0±0**a</td>
<td>3.82±0.04**a</td>
<td>9.55±0.05**a</td>
<td>0.0403</td>
</tr>
<tr>
<td>Karate</td>
<td>81.53±0.15**a</td>
<td>95.54±0.07**a</td>
<td>22.29±0.06**a</td>
<td>50.32±0.18**bc</td>
<td>75.16±0.09**abc</td>
<td>0.0004</td>
</tr>
<tr>
<td>Kelthane</td>
<td>100±0*a</td>
<td>100±0*a</td>
<td>100±0*a</td>
<td>100±0*a</td>
<td>100±0*a</td>
<td>-</td>
</tr>
<tr>
<td>Omite</td>
<td>80.25±0.12**ab</td>
<td>93.63±0.07**a</td>
<td>75.8±0.25**ab</td>
<td>97.45±0.05**a</td>
<td>60.51±0.07**a</td>
<td>0.0363</td>
</tr>
<tr>
<td>Polytrin</td>
<td>100±0*a</td>
<td>78.98±0.21*a</td>
<td>85.99±0.14*a</td>
<td>88.54±0.18*a</td>
<td>87.26±0.15**a</td>
<td>0.6725</td>
</tr>
<tr>
<td>P-values</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

**Means±SE down the columns are significantly different (P=0.05) [Analysis of variance (ANOVA) and Student-Newman-Keuls (SNK)].**
spider mites. This corroborates earlier findings, which reported widespread tolerance of *T. evansi* to this chemical at levels as high as 1000-fold in Zimbabwe (Blair, 1989). Similarly, in other spider mite species, 289.2 fold and 104.7 fold decrease in susceptibility to dimethoate by *Oligonychus pratensis* Banks and *T. urticae* respectively after only 10 cycles of exposure was reported (Yang et al., 2002). Resistance to another organophosphate (chlorpyrifos) by *T. evansi* was also reported in mites from Zimbabwe (Blair, 1989), Malawi and Southern France (Nyoni et al., 2011; Carvalho et al., 2012).

The spider mites which had been maintained in ICIPE laboratory free of any chemicals also showed high levels of tolerance to dimethoate. Therefore, it is not clear whether resistance to some organophosphates is innate in this species or as a result of selection pressures. On the other hand, it is also possible that the ICPE culture could have had prior exposure to chemicals before laboratory rearing. Yang et al. (2002) observed that even after three months without pesticide exposure, there was reduced susceptibility to dimethoate in the two-spotted spider mites (*T. urticae*). However, it is unknown whether this would be the case even after three years of continuous rearing without pesticide exposure as was observed in the current study. This observation is important as it could have serious ramifications for future pest control programs; especially in areas like Athi River and Kiwewi where the farmers perceive that mites have not acquired pest status yet they continue to use broad spectrum chemicals for routine pest management.

With the foregoing, it is possible to conclude, dimethoate should not be recommended for *T. evansi* control but instead, the specific acaricides Omite (propargite) and Keltthane (dicyofol) should be used. From the findings of this study, farmer complaints of inability to control spider mites using the tested chemicals could be attributed to poor application methods due to insufficient knowledge of the pest behaviour. Therefore, there is need for farmer sensitization on proper application methods and acaricide rotation. There are acaricides that have been recently developed with new and complex modes of action that could be used together with other management options or in acaricide rotation strategies in order to delay resistance development. Gotth et al. (2010) reported that bifencinate, cyanophren, milbemectin, spirodiclofen and tebufenpyrad caused high toxicity to *T. evansi* from nine localities in the world. This means that these new products can also be incorporated into acaricide rotations taking into consideration their individual modes of action. The use of acaricides should be limited by adhering to IPM principles including cultural control practices to reduce *T. evansi* populations. In addition, other compatible strategies such as biological control using the phytoseiid mite *Phytoseiulus longipes* Metsch and *Beauveria bassiana* Balsamo (Bugeme et al., 2008; Maniania et al., 2008) could be considered as alternative control agents in order to minimize acaricide use.

### References


SAS Institute, 1990 - SAS users' guide. - SAS Institute, Cary, NC, USA.


