



POPULATION DYNAMICS OF PREDACIOUS PHYTOSEIID MITES, *EUSEIUS KENYAE* AND COFFEE THRIPS, *DIARTHROTHRIPS COFFEA* AND THEIR INTERACTIONS IN COFFEE AGRO ECOSYSTEMS IN KENYA

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ABSTRACT

Several strategies are employed in management of insect pests. Among these, chemical control is a priority to most farming communities where pest incidences occur while other existing options such as biological control are rarely considered. In coffee farming agro ecosystems, there are indigenous biological control agents such as the predacious phytoseiid mites, *Euseius kenyae* (Swirski and Ragusa) that have the potential to manage secondary pests like coffee thrips, *Diarthrothrips coffeae* Williams. This study was conducted to assess the population dynamics of *E. kenyae* and *D. coffeae* as well as their interactions under coffee agro ecosystems where various soil fertilizer sources and selective insecticides were applied as treatments. The populations of both *E. kenyae* and *D. coffeae* fluctuated during the three years study period. The *E. kenyae* suppressed the population of *D. coffeae* under various treated coffee blocks. There was negative correlation between *E. kenyae* and *D. coffeae* in year 2006 and 2008 where the increasing population of *E. kenyae* decreased that of *D. coffeae*. In year 2007, positive correlation between *E. kenyae* and *D. coffeae* was observed in some of the treatments where increased population of *D. coffeae* caused an increased population of *E. kenyae*. *Euseius kenyae* managed to contain the *D. coffeae* population to below economical injury levels (1-2 thrips per leaf) during the three years under the various coffee agro ecosystems. The use of chlorpyrifos never affected *E. kenyae*. Their survival and increased in number under chlorpyrifos treated coffee blocks indicated the development of resistance by the population of *E. kenyae*, hence the possibility of using them as a component in an Integrated Pest Management strategy in coffee.

KEY WORDS: Biological control, secondary pests, soil fertilizer sources, selective insecticides

INTRODUCTION

Coffee farming remains a key foreign exchange earner in most coffee producing countries where it is estimated to support the livelihoods of over 120 million people (Osorio, 2002). Though this is the case, several factors such as the attack by insect pests avert coffee farming in many tropical countries. However, to manage them, control strategies like cultural practices, use of insecticides and bio-agents have been developed and used in complex coffee agro-ecosystem. In most cases, coffee farmers depend heavily on pesticides to control various pests, while other control tactics are almost ignored or inadequately applied. For example, balanced crop nutrition (nitrogen, phosphorous, potassium) improves the tolerance of plants against insect pest infestations and decrease substantially the damage caused by several insect pests such as scales (Bruning and Veblen, 1969). But there are reported cases where the populations of sucking insects are stimulated following intensive nitrogen fertilizer use (Campbell, 1984; Salama *et al.*, 1985). The nitrogen to potassium ratio plays a major role in the host-pathogen relationship in crops such as soybean, rice, barley and sesame (Last, 1962; Perrenoud, 1990; Härdter, 1997; Sweeney *et al.*, 2000; Mondal *et al.*, 2001). Plants supplied with all necessary nutrients in balanced manure

are more resistant to insect pests and diseases (Krauss, 2001). Shah *et al.* (2003) established that the abundance of epigeal coleopteran fauna (polyphagous predators in agro ecosystems) was greatest in organically managed farms as compared to conventional farms, a situation that was related to greater food resources from weeds, seeds and prey availability from the invertebrates associated with organic manures. According to Workneh and Van Bruggen (1994), and Knudsen (1995) organic matter acts on insect pests and diseases partly through increased soil microbial activity that leads to increased competition, parasitism and predation in the rhizosphere. According to Van Bruggen and Termorshuizen (2003), and Hiddink *et al.*, (2005) soils with higher biological diversity, such as natural or organically managed agricultural soils are frequently more suppressive to soil-borne diseases than conventionally managed agricultural ones. In a natural ecosystem, two groups of agro-pests exist; primary pests and secondary pests. Primary pests require application of chemical control strategies in order to stop any damage occurring on the expected crop yield. Where this is the case, the secondary pests are biologically managed and contained below economic injury levels by several bio-control agents such as predacious phytoseiid mites (Fleschner, 1958). Hence the growers are encouraged to conserve bio-control agents either through

reduction of toxic inputs in the agro- ecosystem or application of environmentally safe compounds (El-Banhawy, 1997).

The use of selective insecticides helps to improve conservation of natural enemies thereby contributing to the success of integrated pest management (IPM) programmes (Galvan *et al.*, 2006). Study by Galvan *et al.*, (2006) showed that Ladybird beetle, *Harmonia axyridis* (Pallas), was tolerant to selective insecticide, Spinosad (Tracer). Other Insecticides such as chlorinated hydrocarbons are known to be highly toxic to many mite predators while others have limited direct effects (El-Banhawy, 1976). Tolerance to DDT has been observed in larvae of *Chrysopa* spp and *Anthocoris musculus* (Say), and several species of phytoseiids; *Amblyseius fallacis* Garman and *Typhlodromus caudiglans* Shuster (El-Banhawy, 1976). According to El-Banhawy (1997), several insecticides commonly applied for pest control in fruit trees never affected the population of predacious mites which acquired resistance against these insecticides following their application for many years. In a commercial farming system of crops such as citrus, both primary and secondary pests infesting crops exist, and the farmers are supposed to integrate control of target pest with the secondary ones without observable negative effects on the other. According to Adan *et al.*, (1996) application of selective insecticide for the target pest is recommended while the natural enemies suppress the population of secondary pests with the expectation that little interruption of natural enemies is caused by selective insecticide such as spinosad. At present, following intensive genetic studies of natural enemies like predacious mites, it is possible to select insecticide resistant strains. These selected strains can be employed in agro-ecosystems like citrus and other crops such as coffee where the predators are biologically expected to manage secondary pests and in the meanwhile the selective insecticide chemically control the primary pest without interference to the behavior of the selected natural enemy (Hoyt, 1969; Hoyt and Caltaginare, 1971; Croft, 1982; Hoy *et al.*, 1982). Populations of predacious phytoseiid mites with developed resistance to most commonly used insecticide (Chlorpyrifos) in coffee agro-ecosystems to control primary insect pests such as Coffee Berry Borer, *Hypothenemus hampei* Ferri has been established (Mugo *et al.*, 2011).

Essentially, coffee plants host many mite species that are either beneficial or harmful during the cropping cycle. The red coffee mite, *Oligonychus ilicis* (McGregor), and the false spider mite, *Brevipalpus phoenicis* (Geijskes) are important pest mites of coffee (Pallini *et al.*, 2008). Their natural enemies are mainly the predatory mites of the family Phytoseiidae (Pallini *et al.*, 2008). In Kenya several species of predatory mites associated with coffee have been identified (El, Banhaway *et al.*, 2009; Mugo, 2010). The phytoseiids among other factors play an important role in controlling tetranychids throughout the world (Collyer and Kirby, 1955). The majority of

phytoseiid mites are facultative predators that feed on a wide range of prey including red spider mites, gall and rust mites and thrips such as *Diarthrothrips coffeae* Williams found in coffee. Other species also feed on fungal spores, pollen, honey dew and exudates from plants, but rarely plant tissue (Zhang, 2003; Vega *et al.*, 2007). In coffee farming, *D. coffeae* is the most damaging species of thrips especially in East Africa (Le Pelley, 1968). It occurs on coffee in very small numbers, but can increase to populations likely to cause severe damage. Normally, this pest is a serious threat under hot dry weather conditions and especially where the soil is dry and lacking in humus. In Kenya, *D. coffeae* increases in numbers about the end of the dry season in February and March following the hot dry weather experienced from December to March. However, this is not always the case especially where predacious Phytoseiid mites, *Euseius kenyae* (Swirski and Ragusa) are adequately conserved by use of fertilizer sources such as Organic Compost and safe insecticides (Mugo, 2010). This study investigated the population dynamics of *E. kenyae* and *D. coffeae* as well as their interactions under coffee agro-ecosystems where various soil fertilizer sources and selective insecticides were applied to control key coffee insect pest, Coffee berry borer.

MATERIALS AND METHODS

An experiment on different integrated systems for pest control was carried out at Coffee Research Station (CRS), Ruiru for three successive years (2006 - 2008). CRS is situated in the main coffee growing agroecozone (UM2) in Kenya and located at an altitude of 1608m a.m.s.l (above mean sea level). The mean annual rainfall is 1058 mm, bimodally distributed with main rainy season (Long Rains) being March- May and Short rains, November- December. The soil at the Coffee Research Station is humic and euric nitosol (Kikuyu Red Loam) which is dark reddish brown to dusky red, very deep (1.5-2.0m), friable and free draining with acid humic topsoil. It is of volcanic origin and is formed *in situ* by the decomposition and leaching of tertiary trachytic lava and tuff deposits. It has high clay content, often of 60-80%, high holding water capacity, good porosity and drainage, and slightly very acidic.

Experimental site

The experiment was laid out at CRS in a main coffee block with mature trees of Arabica coffee hybrid, Ruiru 11 that is resistant to two main coffee diseases; Coffee Berry Disease and Leaf Rust. The trees had a planting of close spacing of 2M x 2M giving a total of 2500 trees per hectare. Agronomic practices such as pruning, liming, handling and weeding were carried out as recommended. A block of 1500 coffee trees of Ruiru 11 was carved out from the main block for the experiment.

Experimental design and treatments

The selected and carved coffee block was sub-divided into three equal medium size sub-blocks each with about 500 trees. The first sub-block was fertilized using compound fertilizer (N.P.K. 17:17:17), the second was organically fertilized using composted manure (made from a mixture of cattle and poultry manures, coffee pulp, banana chippings and trace elements)

while the third sub-block received improved N.P.K (22:6:12). In all the sub-blocks, Gypsum (Lime/calcium source) was applied at a nominal rate of 300g /tree annually according to results of soil analysis so as to improve Calcium level that was found inadequate. Calcium ammonium nitrate (CAN: 26:0:0) was applied as a supplement in the sub-blocks treated with inorganic compound fertilizers as recommended by Coffee Research Foundation (CRF).

Three different plots of 16 trees each, using a Complete Randomized Block Design were distributed in each sub-block. Selective insecticides; Spinosad (Tracer) (a naturally derived compound, which is a mixture of spinosyns A and D - a novel class of macrocyclic lactones produced by the soil actinomycete, *Saccharopolyspora spinosa* (Mertz and Yao)) and Chlorpyrifos (Dursban 480EC) were applied as the treatments with untreated plot as control per sub-block. Each treatment was replicated four times. Two rows of coffee trees were left between the sub-blocks, plots and the periphery as guard rows.

Sampling of coffee Thrips and predacious mites

Four coffee trees at the center of each plot were sampled fortnightly to monitor the population levels of predacious mites. The predacious mites were dislodged from the coffee branches using a beating stick. The beating was conducted for one minute in each plot among the four trees at the centre. The dislodged mites were collected in a collecting board, counted and recorded. The population of coffee thrips was assessed from twenty young leaves randomly selected from four trees at the centre of each plot (five leaves per tree from different directions). On each leaf the number of thrips were counted and recorded.

RESULTS

The presence of *E. kenyae* on coffee trees suppressed the population of *D. coffeae* and other secondary pests. Interaction of *E. kenyae* with *D. coffeae* was negatively correlated during 2006 and 2008 cropping seasons. The increase of *E. kenyae* caused a decrease in population of *D. coffeae* in the two seasons. In year 2007, positive interactions between *E. kenyae* and *D. coffeae* occurred under some treatments where as the population of *D. coffeae* increased that of *E. kenyae* subsequently increased (Figs. 1a, b, and c).

Year 1 (2006)

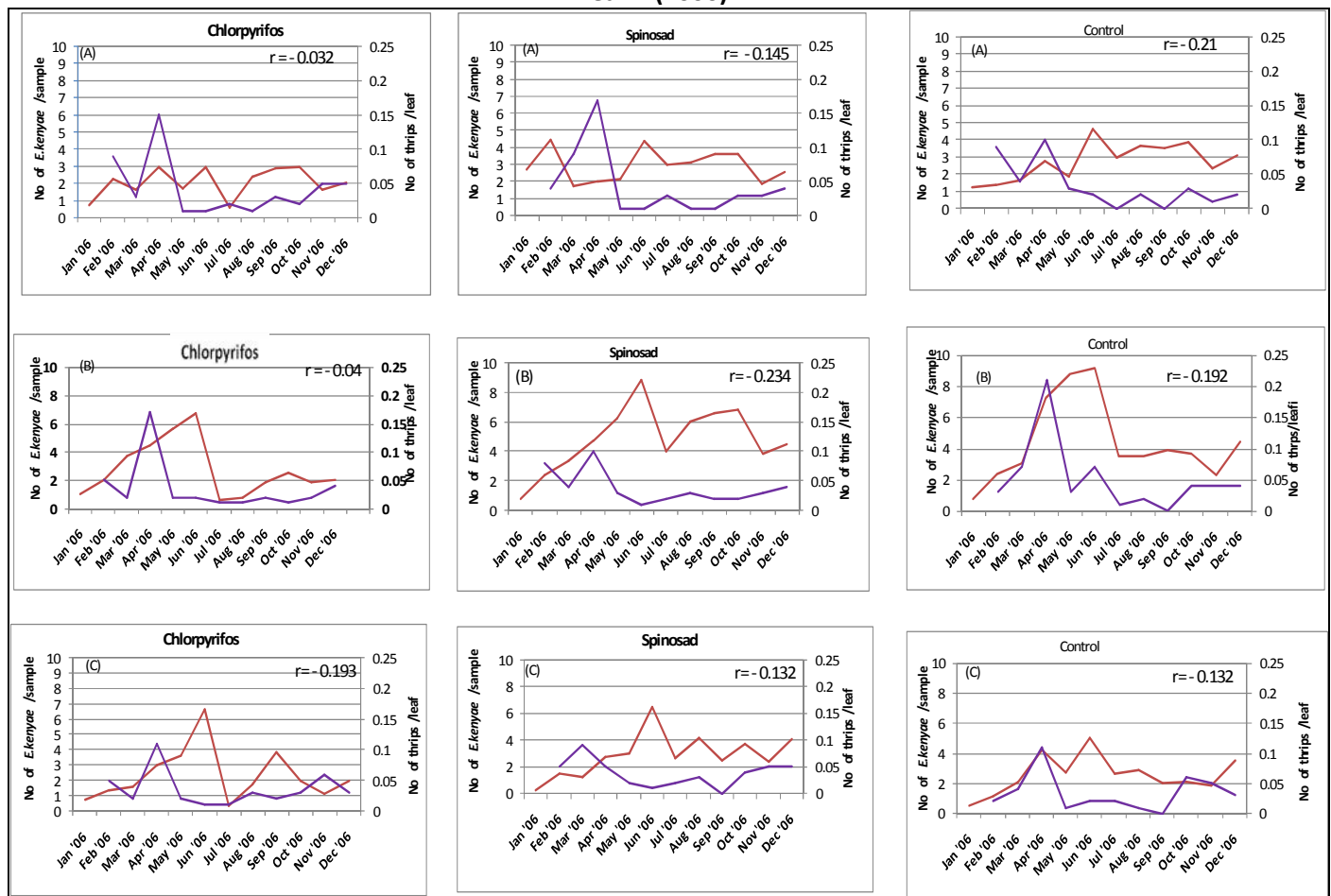


Figure 1a: Number of *Euseius kenyae* (Swirski and Ragusa) and thrips, *Diarthrothrips coffeae* Williams from coffee trees under insecticides (Chlorpyrifos and Spinosad) and different soil fertilizers during 2006.

[(A): N.P.K. 17:17:17 fertilizer; (B): Organic compost (N.P.K. 0.8: 0.2: 1.0); (C): N.P.K. 22:6:12 fertilizer; Control: Insecticides free]

During the year 2006, the population dynamics of both *E. kenya*e and *D. coffeae* varied. That of *D. coffeae* peaked in April leading to increased population of *E.kenya*e where either the Chlorpyrifos, Spinosad or none of the insecticides was applied under different soil fertilizers (Fig. 1a).The increased population of *E.kenya*e from April that peaked in June, managed to maintain the population of *D. coffeae* at a low level throughout the rest of the season (less than one thrip per leaf). The population of *D. coffeae* during the year 2006 remained below the established economic injury levels (below one-two thrips per leaf). Over the same period the population of *E. kenya*e negatively correlated with that of *D. coffeae* (Table 1). That is, as the population of *E. kenya*e increased that of *D. coffeae* declined and vice versa. The population of *D.coffeae* during the month of September was zero or near that level under any soil fertilizer sources and

insecticide treatments but that of *E. kenya*e remained high (Fig. 1a). Despite the absence of *D. coffeae* during some months in the cropping season, *E. kenya*e was still able to sustain high population levels.

In the year 2007, the population of *D. coffeae* in the month of July declined drastically. No thrips were observed on leaves irrespective of Chlorpyrifos, Spinosad or no insecticide application under different soil fertilizers (Fig. 1b). The population of *E. kenya*e remained above zero mites per sample during the same month. Comparatively, the population of *E. kenya*e remained higher than that of *D. coffeae* throughout the year. Unlike in year 2006, the Spinosad and control blocks under both the organic compost and N.P.K. 17:17:17, and the control under N.P.K. 22:6:12, the populations of predatory mites and the thrips were positively correlated (Fig. 1b, Table 1).

Year 2 (2007)

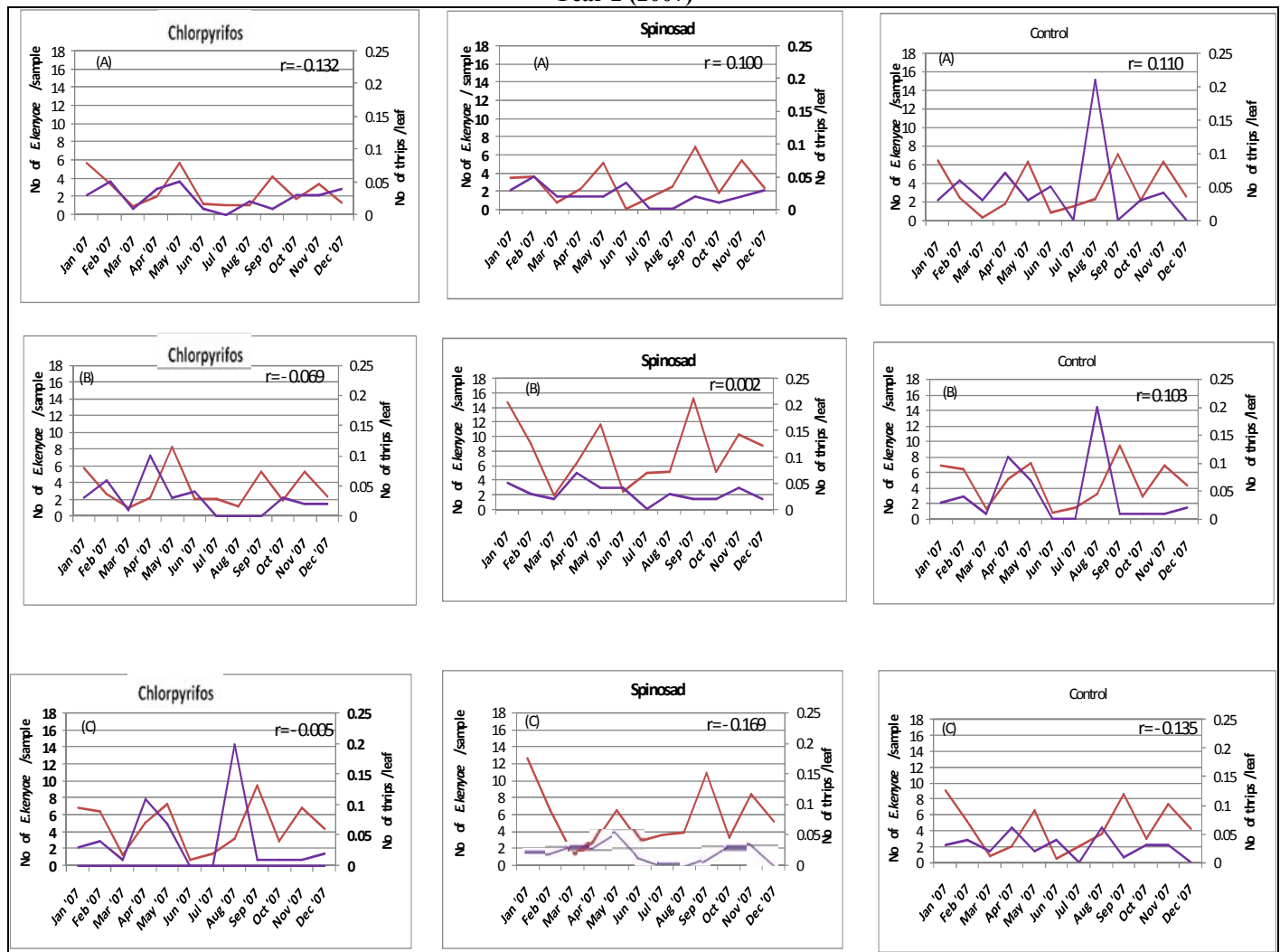


Figure 1b: Number of *Euseius kenya*e (Swirski and Ragusa) and thrips, *Diarthrothrips coffeae* Williams from coffee trees under insecticides (Chlorpyrifos and Spinosad) and different soil fertilizers during 2007.

[(A): N.P.K. 17:17:17 fertilizer; (B): Organic compost (N.P.K. 0.8: 0.2: 1.0); (C): N.P.K. 22:6:12 fertilizer; Control: Insecticides free]

That is, as the population of *D. coffeae* increased that of *E. kenya*e simultaneously increased and vice versa. The thrips and predatory mites' populations during the year 2008 had some variation (Fig. 1c). In the first six months, the population of *D. coffeae* remained high when compared to the rest of the season. However, the population of *E. kenya*e was low during the first six months as compared to the rest of the year (Fig. 1c). The populations of *D. coffeae* and *E. kenya*e reversed from June where the thrips population decreased and in some cases recording zero while that of predacious mites increased. From the month of July the population of *E. kenya*e remained high while that of *D. coffeae* declined to very low levels (Fig. 1c). During the

year, the population of *E. kenya*e negatively correlated with that of *D. coffeae* irrespective of Chlorpyrifos, Spinosad or no insecticide application under different soil fertilizer sources (Fig. 1c, Table 1). The use of both the insecticides and various soil fertilizers had no significant effect ($P > 0.05$) on *D. coffeae* population (Table 2a). Over the three years, the population of *D. coffeae* significantly differed ($P < 0.05$) from one year to the other (Table 2a). The population of *E. kenya*e was highly significant ($P < 0.05$) among the insecticide and fertilizer treatments (Table 2b). The populations of predacious mites during the three years period were also highly significant (Table 2b).

Year 3 (2008)

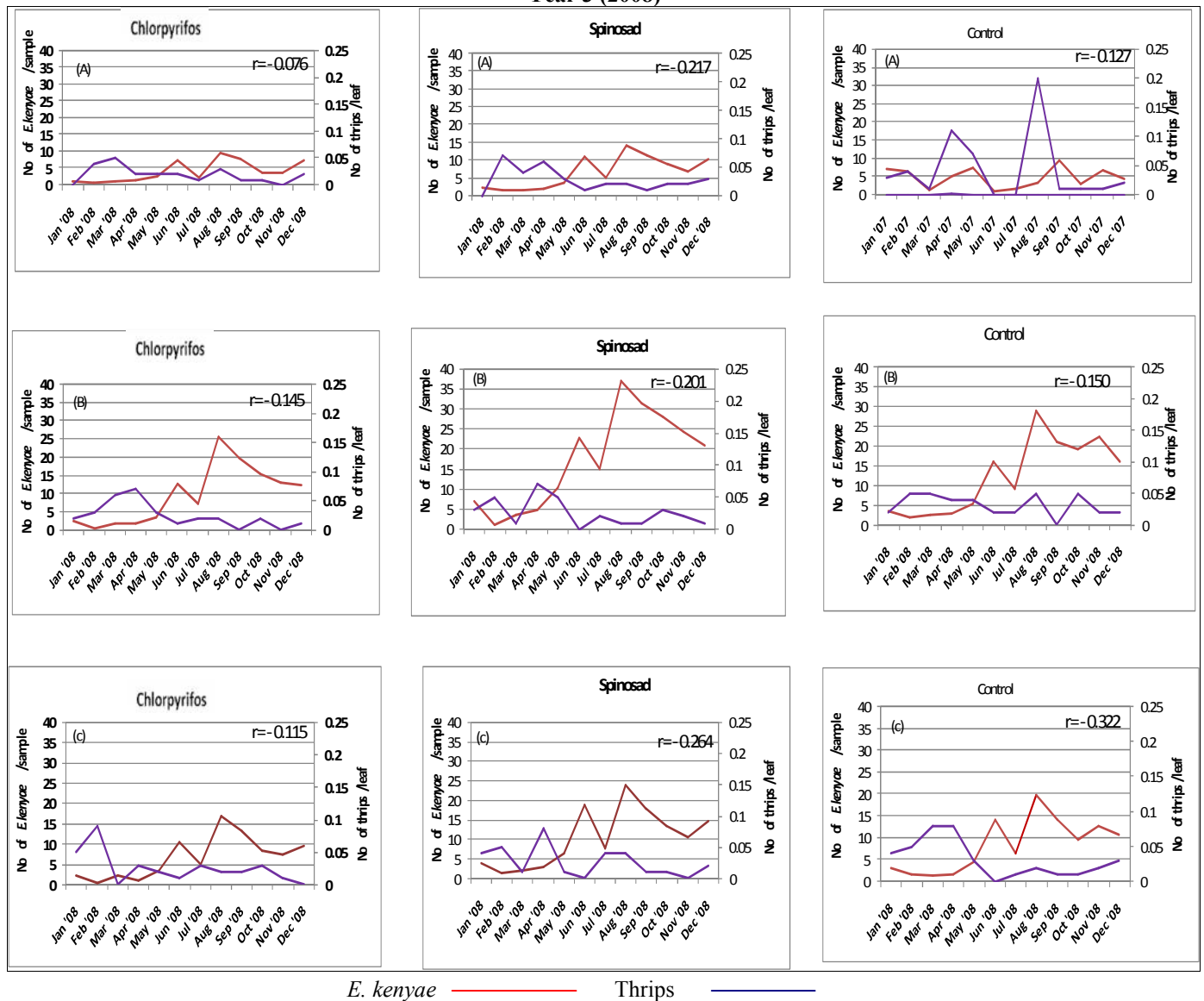


Figure 1c: Number of *Euseius kenya*e (Swirski and Ragusa) and thrips, *Diarthrothrips coffeae* Williams from coffee trees under insecticides (Chlorpyrifos and Spinosad) and different soil fertilizers during 2008.

[(A): N.P.K. 17:17:17 fertilizer; (B): Organic compost (N.P.K. 0.8: 0.2: 1.0); (C): N.P.K. 22:6:12 fertilizer; Control: Insecticides free]

Mites and Thrips population dynamics

Table 1: The relationships between the populations of *Euseius kenyae* (Swirski and Ragusa) and *Diarthrothrips coffeae* Williams when sprayed with Chlorpyrifos and Spinosad under different soil fertilizers in a coffee farm at Coffee Research Station from 2006, 2007 and 2008

Fertilizer source	Insecticide	2006			2007			2008		
		r	D.f	Slope	r	D.f	Slope	r	D.f	Slope
N.P.K. 17:17:17	Chlorpyrifos	-0.032	3	1.021	-0.132	3	1.012	-0.076	3	1.017
	Spinosad	-0.145	3	1.036	0.100	3	0.999	-0.217	3	1.028
	Control	-0.206	3	1.042	0.110	3	0.962	-0.127	3	1.016
Organic Compost (N.P.K. 0.8: 0.2: 1.0)	Chlorpyrifos	-0.040	3	1.025	-0.069	3	1.017	-0.145	3	1.031
	Spinosad	-0.234	3	1.041	0.002	3	1.013	-0.201	3	1.027
	Control	-0.192	3	1.036	0.103	3	1.000	-0.150	3	1.026
N.P.K. 22:6:12	Chlorpyrifos	-0.193	3	1.034	-0.005	3	1.012	-0.115	3	1.029
	Spinosad	-0.132	3	1.033	-0.169	3	1.032	-0.264	3	1.029
	Control	-0.132	3	1.021	0.135	3	1.021	-0.322	3	1.040

TABLE 2: Analysis of Variance for the effect of cropping seasons (Years), insecticides and fertilizers on thrips, *Diarthrothrips coffeae* Williams and predacious mites, *Euseius kenyae* (Swirski and Ragusa).

a) Thrips

Parameter	Source	DF	SS	MS	F Value	Pr < F
No. of Thrips	Insecticides	2	0.00288825	0.00144413	1.81	0.1660 ^{ns}
	Fertilizers	2	0.00166159	0.00083079	1.03	0.3568 ^{ns}
	Year	2	0.00730063	0.00365032	4.65	0.0102 ^{**}
	Treatment	8	0.00537016	0.00067127	0.83	0.5753 ^{ns}
	Year*Treatment	26	0.02010753	0.00077337	0.96	0.5251 ^{ns}
	Rep	11	0.06240610	0.00567328	7.03	<.0001 ^{***}
	Error	277	0.22339617	0.00080648		

b) Predacious mites

Parameter	Source	DF	SS	MS	F Value	Pr < F
No of mites	Insecticides	2	375.012719	187.506359	7.25	0.0008 ^{***}
	Fertilizers	2	824.409172	412.204586	16.89	<.0001 ^{***}
	Year	2	2044.666835	1022.333418	49.94	<.0001 ^{***}
	Treatment	8	1329.668483	166.208560	7.16	<.0001 ^{***}
	Year*Treatment	26	3987.205206	153.354046	9.96	<.0001 ^{***}
	Rep	11	1750.419127	159.129012	10.33	<.0001 ^{***}
	Error	286	4403.63090	15.39731		

Note: Treatment = Fertilizer x Insecticide

DISCUSSION & CONCLUSION

Control of insect pests by use of bio-control agents is one of the options towards ecologically viable solutions in pest management. Predacious mites for instance, control insect pests such as thrips and restrain them below economic injury levels. The predacious mites, *E. kenyae* population during the year 2006 when this study started were low. They increased with time despite the application of Chlorpyrifos and Spinosad, and various soil fertilizer sources. It was expected that where Chlorpyrifos and Spinosad were sprayed, the population of predacious mites would rapidly drop possibly to zero. This never happened, meaning that the mites were less susceptible to the two insecticides. Studies by Mugo (2010) and Mugo et al., (2011) indicated that some

populations of *E. kenyae* are resistant to Chlorpyrifos, the commonly used insecticide in coffee to manage key insect pests such as the Coffee berry borer and Antestia bugs. Under such a situation the survival of predacious mites is an advantage as the mites would control secondary pests of coffee such as coffee thrips and red spider mites. During the year 2006, the population of *D. coffeae* declined to zero levels in the month of September but that of *E. kenyae* remained high. The survival of *E. kenyae* in absence of *D. coffeae* indicated their ability to survive on other food sources. And according to Vega et al., (2007) some species of phytoseiids feed on fungal spores, pollen, honey dew and exudates from plants. During the three years of this study, the number of *D. coffeae* remained below 0.2 per leaf which

was below the established economic injury levels of two thrips per leaf (Anon, 1989). The peaking of thrips population in year 2006, 2007 and 2008 indicated some variations. This was likely due to weather changes during the study period. Thrips are known to increase in their infestation when it is dry or there is prolonged drought but decreases with onset of rains probably due to favourable weather conditions that enhances the bio-control agents such as the fungal pathogens. The use of Chlorpyrifos and Spinosad showed no distinct effect on *D. coffeae* under any soil fertilizer sources meaning that they had equal effect on the population of *D. coffeae*. The impact of predacious mites was the other possible cause, where under natural ecosystem these mites were expected to keep the population of thrips to below the economic injury levels. Though it was established that insecticide like Chlorpyrifos significantly reduced the population of predacious mites when compared to Spinosad and the controlled coffee plots, it meant that the population that remained was adequate and able to contain the thrips to below the economic injury levels. This also indicated that the strain of predacious mites that occurred in the field had to some extent a degree of resistance to Chlorpyrifos as they progressively increased in number with continuous usage of this insecticide.

In the present study the *E. kenya*e population in the different treatments remained above that of *D. coffeae*. A negative correlation existed mainly between the predacious mites and the thrips. This means as the population of predacious mites increased that of *D. coffeae* decreased simultaneously and vice versa. Thus, *E. kenya*e was considered a valuable natural enemy under coffee agro ecosystem as it controlled other minor pests such as scales, aphids and spider mites. During this study, there was no severe infestation experienced from any of these pests regardless of the treatments. On the other hand, probably the use of selective insecticides helped in creating an environment where a number of natural enemies together with *E. kenya*e, adapted themselves, increased and suppressed the populations of other minor coffee insect pests. According to the findings, the organic compost had a significantly ($P < 0.05$) higher population of predacious mite than N.P.K. 17:17:17. The population of predacious mites under N.P.K.17:17:17 and N.P.K. 22:6:12 were not statistically different ($P > 0.05$) from each other. The presence of significantly higher predacious mites' population under organic compost indicated a situation of improved soil conditions or quality environment with many toxic free nutrients. Organic matter tends to improve soil physical and chemical properties, hence increase in number of microorganisms (Awad et al., 1993). In this study the balance between N: P: K and the presence of other elements such as Calcium, Magnesium, Zinc, Boron and Iron in the organic compost enhanced the quality and vigorosity of the coffee trees. The encountered vigour by the coffee trees and high population of *E.kenya*e, jointly, probably reduced the damage likely to have been caused in the coffee farm by the minor pests.

*Euseius kenya*e is a bioagent with potential to manage *D. coffeae* in a coffee agro-ecosystem and to be used as a

component within the integrated pest management strategy. The survival and existence of *E.kenya*e under coffee sprayed with Chlorpyrifos is an evidence of existing strains that are resistance to Chlorpyrifos or strains that progressively acquired resistance following their exposure to the Chlorpyrifos.

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