Innovative Strategies for Control of Coffee Insect Pests in Tanzania: A Review

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Abstract: *Coffee insect pests are one of the major factors which affect coffee production and quality. globally, coffee insect pests are estimated to cause losses of about 13%. However in Africa, yield losses can be much higher, particularly where Arabica and Robusta coffee are grown for a long time. In Tanzania the major insect pests are white coffee stem borer (Monochamus leuconatus), coffee berry borer (Hypothenemus hampei), Antestia bugs (Antestiopsis spp), leaf miner (Leucoptera spp), green scale (Coccus spp) and mealy bugs (Planococcus kenyae). Minor important pests including yellow headed borer (Dirphya nigricornis), thrips (Diarthrothrips coffeae) and berry moth (Prophants smaragdina) are reported to vary in crop losses caused. For decades industrial chemicals have been used to control the prevailing coffee insect-pests. But uses of industrial chemicals have been reported to have negative implications to the environment, animals and human health. In the recent years worldwide, efforts have been focused to researching on the sustainable control measures for coffee insect pests. For a period of over ten years Tanzania Coffee Research Institute (TaCRI) has been developing ecologically and environmentally sustainable coffee insect-pests control measures which include; use of bio pesticides, traps, parasites, attractants and biological agents. These technologies are progressively adopted by coffee farmers in the country. The potential of these innovative insect pests control measures and their impacts on management of coffee insect pests are discussed in this review paper.*

Key words: Coffee insect pests, Arabica, Robusta, IPM strategies

INTRODUCTION

Coffee is one of the five most important commodities in the world market (Ibrahim and Zailani, 2010). Nestle (2004) and DaMatta, (2004) describe coffee as the second most valuable legally traded commodity in the world after petroleum, representing a significant source of income to several tropical and sub-tropical countries. It is the primary export of many developing countries, and as many as 25 million farmers depend on coffee for their livelihood. It also provides significant foreign exchange earnings of many developing countries (Waller *et al*., 2007; Kaplinsky, 2004). In Tanzania coffee accounted for 25% of the crops exports value in the year ending June 2013 (BOT, 2013). Coffee subsector employs more than 400,000 smallholder farmers in Tanzania who produce 90 – 95% of coffee while the remaining 5 -10% is produced by 110 coffee estates. It is estimated that 2,000,000 other people depend on coffee indirectly (TaCRI, 2011).

PESTS OF ECONOMIC IMPORTANCE IN TANZANIA AND THEIR IMPACTS TO COFFEE PRODUCTION

Insect pest problem is one of the major factors which affect coffee production and quality (Hella *et al*., 2005). Over 900 insect species are known to infest coffee in the world (CABI, 2007; Kimani *et al.,* 2002; Hillocks, 2001). Globally, coffee insect pests are estimated to cause losses of about 13% (Bardner, 2006). However in Africa, yield losses can be much higher, particularly where Arabica and Robusta coffee is grown for a long time. About 36 insect pests have been recorded in East Africa including Tanzania (Mbungua, 1995; Mugo, 1994).

In Tanzania the major insect pests include the following; the African white coffee stem borer, *Monochamus leuconatus*, Pascoe is a serious pest in Africa coffee growing countries, including Tanzania, causing production losses, severe damage to trees and in some cases, substantial tree mortality if not controlled (Le Pelley, 1968). The pest causes a yield loss as high as 25% in South Africa (Oduor and Simons, 2003; Schoeman, 1998). Antestia bug is a major coffee pest with a density of 2 to 3 per tree considered as the economic threshold level and caused a crop loss of 45 % (Le Pelley, 1968).

The coffee berry borer, *Hypothenemus hampei* is serious coffee pest worldwide and major pest for Robusta and low altitude Arabica coffee (Rutherford and Phiri, 2006). Crop losses caused by this pest can be severe, ranging from 50-100% of berries attacked if no control measures are applied (Le Pelley, 1968). Waterhouse and Norris (1989) reported a yield losses as high as 96% due to attack by this pest in Africa. The leaf miners (*Leafminer spp*) is another pest of economic importance which attacks more Arabica than Robusta. Density of 4 mines per leaf make a maximum number of a leaf to fall and causes losses that may reach 50% of the total production (Motte, 1976). The green scale, *Coccus alpinus* De Lotto and *Coccus viridis* Green are common but minor insect pest of mature Arabica coffee. Damage caused by the pest will in turn lead to decreased yield and low quality coffee beans (Minai, 2009; CABI, 2007). The coffee mealy bugs, *Planococcus kenyae* Le Pelley are important sucking pests of Arabica and Robusta coffee. Serious infestations of the pest are often found where there has been use of insecticide sprays, especially highly toxic Organophosphate sprays (CABI, 2007; Wrigley, 1988). Other coffee pests of minor but importance include; yellow headed borer, *Dirphya nigricornis* (Olivier) berry moth, *Prophantis smaragdina* (Butler) and Thrips, *Diarthrothrips coffee* (Williams) (Magina, 2011; Minai, 2009; Le Pelley, 1968).

MANAGEMENT OF COFFEE INSECT PESTS

For decades industrial synthetic chemicals have been used to control coffee insect-pests. However industrial chemicals have several negative implications to the environment, animals and consumers of coffee (Horrigan *et al.,* 2003). Also use of pesticides results losing market of our coffee to some countries with niche markets that have set Maximum Residue Levels (MRL) (e.g. Japan). In the recent years worldwide, efforts have been focused on identifying alternative strategies which are cost effective and sustainable control measures for coffee insect pests. Integrated pest management (IPM), as one component of Integrated Crop Management, uses a combination of available and compatible pest control methods to minimize pest damage by most economical means, and with the least possible hazard to people, property, and the environment. Consideration of management practices is given to acceptability, ecological stability, environmental safety, and human resource development (CABI, 2007). For over ten years Tanzania Coffee Research Institute (TaCRI) has developed a number of IPM strategies and improved some technologies which are ecologically and environmentally friendly in controlling coffee insect pests.

IPM TECHNOLOGIES DEVELOPED

The technologies developed by TaCRI include the following: use of bio-pesticides (botanicals), sticky traps, entopathogenic fungus, attractants (locally made brews) and biological agents. The technologies developed are progressively disseminated to farmers through participating agricultural shows, open days, demonstration plots, backstopping programme and publications to coffee farmers

Technologies developed by TaCRI

(a) Management of Antestia bugs by use of bio pesticides

Botanical bio-pesticides are naturally occurring chemicals which are extracted from plants (Isman, 2006; Silva, 2004). Botanicals have shown to have short residual effect and are at best, moderately effective in killing insect pests and they are biodegradable, breaking down quickly as compared to synthetic industrial chemicals. Currently Antestia bug is controlled by application of Chlorpyrifos which are synthetic industrial chemicals (Magina, 2011). Some botanicals with insecticidal properties has been used to control insect pests as industrial chemicals on several crops including coffee in Tanzania (Mwatawala, 2005; Paul *et al.*, 2001), however appropriate dosages and their active ingredient (AI) have not been established (Magina; 2011; Paul, 2001). TaCRI has collected about 11 plants believed to have insecticidal properties and established them in the botanical garden at TaCRI-Lyamungu for the purpose of evaluation of their effectiveness for coffee pest management.

Among the botanicals, Fish bean (*Tephrosia vogelii*) has been evaluated against management of Antestia bugs. Fresh extracts of *T. vogelii* at a rate of 1.2 kg per 1 litre of water have been evaluated and observed to be effective as Chlorpyrifos and has been recommended to be used as an alternative for management of Antestia bugs in the field (Magina *et al*., 2012). Research to evaluate the active ingredient (AI) of *T. vogelii* has been initiated in collaboration with Tropical Pesticide Research Institute (TPRI) based in Arusha region.

(b) Alcohol traps for management of coffee berry borer (CBB)

Mass trapping technique by use of attractant is currently being considered worldwide as one of the best ways to control CBB in the field (Durfour and Frerot, 2008). Various authors have reported to establish the control of adult CBB by use of traps baited with lures such as methanol and ethanol in the ratio of 1:1 (Prakasan *et al*., 2001), methylated spirit and water in the ratio of 1:1 (Magina, *et al.,* 2006); and local brews ("mbege", "dengelua" and "rubisi") and banana juice (Magina *et al.,* 2014) respectively. TaCRI, in collaboration with IPM Collaborative Research Supportive Project (IPM/CRSP) in East Africa, has evaluated different attractants, which include; banana juice, local brews ("mbege", "rubisi" and "dengelua"). Results showed these lures and observed to be effective in management of the pest (Magina *et al*., 2014). The attractants perform better when used in the red painted bottle traps locally made by use of discarded plastic bottle (used for packing drinking water). The trap reduces the infestation of the pest damage in the field by 80 – 85% per year, when entrapped with methylated spirit. The trap is an improvement of BROCAP™ trap developed by CIRAD which is still an inaccessible by resource poor farmers in the developing countries in the world. Also the trap has the capacity to capture 300 to 500 adult coffee berry borer in the field per week. The trap made by TaCRI is inexpensive, environmentally friendly and can be easily used by small holder farmers for management of CBB in the field (Figure 1). The technology has been recommended to be used by coffee farmers in Tanzania. Due to its cheapness and simplicity to make, some coffee estates and small holder farmers in the country where CBB is a problem has started adopting the technology.

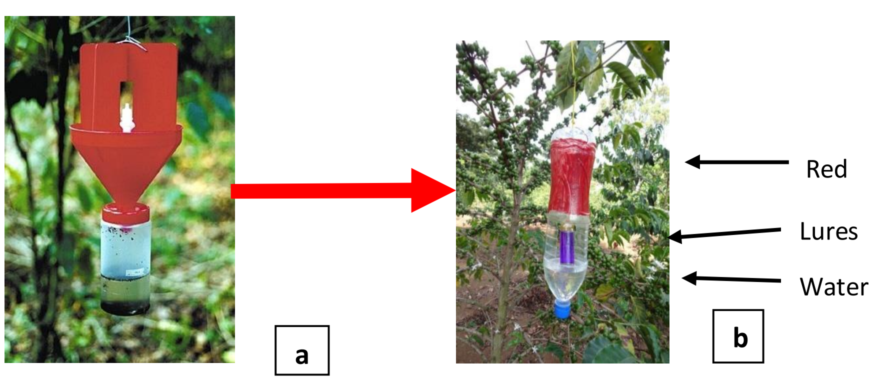

Figure 1: Brocap trap type ("a") from CIRAD and TaCRI trap type ("b") for coffee berry borer in the field

(c) Management of African white stem borers by the use of cooking oil/animal fats

In the past the African white coffee stem borer was effectively managed through use of Aldrin and Dieldrin 18 % EC chemicals. However, these chemicals are no longer used due to their hazardous effects on the environment and non-target organisms and also risk to the user (Rutherford and Phiri, 2006; Magina, 2011). There has therefore not been any effective control measure for the pest to date. Among other cultural management used for management of the pest, TaCRI has evaluated cooking oils and animal fats as an attractants of ants which minimizes the infestation of the pest. Smearing oils or animal fats on the holes made by larvae of the coffee stem borer attracts ants to feed on oils and fats and eventually enter and kill stem borer larvae in the tunnels (Magina, 2011). The technology has been evaluated and recommended to coffee farmers in Tanzania.

Management of mealy bugs and green scales by the use of predators (ladybird beetles)

Predators are mainly free-living species that directly consume a large number of preys during their whole lifetime. Ladybird beetles are typical predators that feed on a wide range of insect prey, and have been used extensively in the bio-control of insect pests (Dixon, 2005). Most lady bird beetles are beneficial as both adults and larvae, feeding primarily on aphids, mites, scale insects, small insects, and insect eggs (Shelton, 2005). According to Leppla and Johnson II (2010) in Florida (USA) they have managed to multiply the predator and they are selling them commercially to other countries for uses in orchards and field crops for management of insect pests. TaCRI has collected and evaluated the feeding habits of about six different types of ladybird beetles naturally occurring at Lyamungo (Hai district) in Kilimanjaro region.

These were identified as the black lady beetle, *Exochomus aethiops*, striped lady beetle, *Cheilomenes propinqua,* black spotted lady bird beetle, *Cheilomenes lunata,* red chilocorus, *Chilocorus circumdata,* Indian wave striped ladybug, *Cheilomenes seximaculata* and spotted potato ladybird beetle, *Henosepilachna vigintioctopuntata.* Among the six species four of them namely as *C. propinqua, C. lunata, C. circumdata* and *E. aethiops* were observed to feed on coffee mealy bugs, scale insects and aphids. The other two species feed on foliage of Cucurbitaceae (e.g. cucumber, pumpkins, water melon and common beans). TaCRI has initiated the process of mass multiplication in the insectary and the progress is encouraging, although a small number of the pests still reach the adult stage. TaCRI is also in process to collaborate with ICIPE for capacity building for rearing protocols of the predators.

Technologies adopted from other countries

(a) Management of thrips and leaf miners by the use of coloured sticky traps

Insect traps are used to monitor or directly reduce populations of insects or other arthropods. Traps warn of pest presence, hot spots, and migration. They also provide a relative measure of insect density through comparisons of the number of adults caught (Weinzierl, *et al.,* 2005; Kronkright, 1991). Edelson *et al.* (2003) indicated that yellow, blue and white sticky traps attracts a range of flying pests, including, thrips, whitefly, moths, aphids, whitefly, fruit fly and leaf miner. TaCRI has modified instead of using the yellow sticky traps made of special paper they modified and use of plywood (30 cm x 30 cm) painted yellow and spread with petroleum jelly or used motor oil on yellow painted plywood.

The trap has indicated non-significant difference ($P>0.05$) as compared with the yellow special papers recommended to attract and capture the moths of coffee leaf miner and thrips which are not easily accessible to our coffee farmers and not available in Tanzania. For example mean thrips trapped per week for special yellow sticky paper and ply wooden made are 489.1 and 475.2 respectively. The locally made yellow sticky traps made of plywood by TaCRI are recommended to be used together with other management practices to minimize the infestation of thrips and leaf miners in the field. TaCRI is in the process to evaluate the efficacy of the same trap for the control of other flying coffee pests such as whiteflies, aphids (winged forms) and moths of leaf skeletonizer, berry moth and fruit fly.

(b) Management of coffee berry borer (CBB) by the use of entomopathogenic fungi (*Metarhizium anisopliae*)

Metarhizium anisopliae (Metschnikoff), *Beauveria bassiana* (Balsamo) and *Vertillium lecanii* (Zimmerman) are entomopathogenic fungi that occur naturally in the environment. The fungi are potential as biological control agents against many insect pests (Prasad and Pal, 2014). They are the most prevalent fungi attacking CBB populations in African countries where this insect originated, as well as in those countries where the borer has spread, including Brazil (Bustillo *et al.,* 1998). Several attempts have been made throughout the world to use mass-produced bio-pesticides based on entomopathogenic fungi for management of CBB and other pests. In Brazil, the role of *B. bassiana* and *M. anisopliae* was evaluated for regulation of CBB populations that emerged from the fallen berries, and persistence of fungi in the soil (Bustillo *et al.,* 1999). Effectiveness of *M. anisopliae* for management of CBB in the laboratory at TaCRI-Lyamungu was evaluated and it was considered to perform well. Mass multiplication of the fungus (fungus sporulation) has been evaluated in several countries by the use of locally available agricultural and industrial waste for a cheap and substrate for the low cost of production (Latifin *et al.,* 2014; Prasad and Pal, 2014). TaCRI has adopted and succeeded in mass multiplication of the fungus by use of rice grain in the laboratory. The way forward with TaCRI is to evaluate the effectiveness of the same fungus in management of the pest in the field.

(c) Management of coffee berry borer by the use of parasitoids

A parasitoid is an organism that lives on or in a host organism and ultimately kills the host. These beneficial species are common in most natural communities and, although their presence is often unnoticed, they help maintain the "balance of nature" by regulating the density of their host or prey population (Smith and Capinera, 2015). Several parasitoids of coffee berry borer have been investigated in various coffee growing countries in the world including; Africa, America, the Caribbean, Oceania and Asia (Vega *et al.,* 2009).

In Colombia three species of bethylid wasps, *Prorops nasuta* Waterston, *Cephalonomia stephanoderis* Betrem, and *C. hyalinipennis* Ashmead, attack the coffee berry borer, *Hypothenemus hampei* (Ferrari) (Coleoptera: Scolytidae), by both predation and parasitism (Vegas *et al.,* 2009). Recent survey by TaCRI in collaboration with IPM Collaborative Research Supportive Project (IPM/CRSP) in East Africa, has identified the presence of *P. nasuta*, *C. stephanoderis* as potential parasitoids naturally occurring in the coffee farms in Kilimanjaro region (Magina *et al.,* 2012). The way forward with TaCRI is mass multiplication and later release in coffee farms infested with the pest. Capacity building on mass rearing techniques of the parasitoids has been initiated between International Centre of Insect Physiology and Ecology (ICIPE) and TaCRI, Lyamungu.

CONCLUSION

This paper has discussed the achievements made by TaCRI in the past twelve years in the area of Integrated Pest Management (IPM). Some IPM techniques have been adapted, with some modifications from other countries while others, like the coffee berry borer trapping have undergone such heavy modifications as to become our own innovations. It is the authors' opinions that the achievements for twelve years are substantial. TaCRI is committed to continue in its meticulous research in IPM so as to have in place an appropriate IPM package which is ecologically and environmentally friendly for coffee farmers in Tanzania. In so doing we will have helped the coffee industry in the country to penetrate the lucrative, but restrictive, niche coffee markets in some countries which have set the maximum residue levels (MRL).

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