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The Discovery of a Green Wood Beetle *Diastocera trifasciata* (Coleoptera: Lamiinae) on Mango Tree in South Sudan

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Abstract: The green wood insect beetle which was later identified as *Diastocera trifasciata* ((Fabricius)-tribus Ceropplesini, Coleoptera: Lamiinae) was found on September 18, 2015, girdling a mango twig at Dr. John Garang Memorial University of Science and Technology (Dr. JG-MUST) campus, Bor county, Jonglei state, Republic of South Sudan. The beetle *D. trifasciata* attacks young vigorous growing mango branches of more than 20-35 mm circumferences. Severely cut branches dried up and broken away especially when there was a strong blowing wind or just remained dry, hung on the tree. Although this incidence may seem not to pose a significant economic threat at the moment, the authors keenly advocate for proactive pest surveillances, monitoring and evaluating its spread, impact damage level caused on mango plants in most areas of high mango productivity and developing control strategy that will prevent further devastations of mango trees, guarantee high fruit yields and ensure food security in South Sudan.

Key words: *Analeptes trifasciata*, beetle, *Diastocera trifasciata*, mango, South Sudan.

1. Introduction

South Sudan is potentially a rich country endowed with abundant natural resources including oil, fertile land, capable of supporting diverse agricultural activities [1], plenty of fresh water reservoirs "Sudd" "130,000-150,000 km^2" with estimated 30% forest cover [2]. The forestry of South Sudan harbours globally significant biodiversity, serves as globally significant green-house sink and provides numerous other goods and services to the population [3]. The agricultural sector, which provides the main source of livelihood to over 80% of the population, is predominantly rain-fed, with annual rainfall levels increase from North to South and from East to West, ranging from less than 500 mm/year in the semi-arid lands of Eastern Equatoria, to around 1,800 mm/year in the Green Belt zone [4].

Mango tree, *Mangifera indica* is a product of the forestry resources and of a great potential as an economic crop especially in the areas of the Green Belt zone of Greater Equatoria region in Republic of South Sudan [5]. The plant is rare, absent or grown as an ornamental in the arid flood plain zones of Eastern Equatoria towards Jonglei state of the Greater Upper Nile region, with no purpose of economic plans. It is therefore, almost considered as an ornamental because of its poor yield and adoption performances, although it could be a potential source for establishing a "fruit juice industry" in South Sudan, if there was peace and given ambient room for strategic economic planning. Nevertheless,

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mango tree, like any other plants, experiences devastation by a number of insect pests [6].

Some of the high exotic mango pests, identified in the Bio-security Plan [7], included the oriental fruit fly complex, that caused 100% fruit loss; the mango pulp weevil, caused high economic losses to mango industry in Asia; mango malformation disease, caused malformed shoots, inflorescences panicles thickened, with large flowers and inflorescences appeared crowded. The mango gall midge found in India, Africa and Malaysia laid eggs on leaves which caused small red spots, heavily galled leaves curled up and dropped off prematurely, resulted in dieback of whole branches in susceptible cultivars and any of these pests would have serious consequences should they enter and become established in Australia [7].

Among all the known mango pests, hoppers, *Idioscopus clypealis*, *I. nitidulus* and *Amritodus atkinson* are considered as the most serious and widespread pests. Large numbers of nymphs and adult insects puncture and suck the sap of tender parts, thereby reducing the vigor of the plants; heavy puncturing and continuous draining of the sap causes curling and drying of the infested tissues [8]. The nymphs and adult stages of these insect pests damage the crop by secreting a sweet sticky substance which facilitates the development of the fungus *Meliola mangiferae* (sooty mould) affecting adversely the photosynthetic activities of the leaves [8]. The second, mealy bugs, *Drosicha mangifera* nymphs and adults suck the plant sap and reduce the vigour of the plant [8]. Excessive and continuous draining of plant sap causes wilting and finally drying of infested tissues and also secretes honey dew, which facilitates the development of the fungus *M. mangiferae* (sooty mould). The third, the inflorescence midge, *Erosomyia indica*, infests and damages the crop in three different stages. The first attack is at the floral bud burst stage. Eggs are laid on newly emerging inflorescence; the larvae tunnel the axis and thus destroy the inflorescence completely. The mature larvae make small exit holes in the axis of the inflorescence and slip down into the soil for pupation. When the tender fruits are attacked they slowly turn yellow and finally drop. The third attack is on tender new leaves encircling the inflorescence. The most damaging one is the first attack in which the entire inflorescence is destroyed even before flowering and fruiting. The inflorescence shows stunted growth and its axis bends at the entrance point of the larvae [9]. Studies conducted on the cashew stem girdler [10], *Analeptes trifasciata*, and a major insect pest of cashew in Nigeria causing economic damage in cashew plantations even at low density. In the studies, newly emerged adults of *A. trifasciata* reared from field-infested cashew stems sexed, and the guts dissected to reveal the internal structures of the insects. The dissected gut compartments showed the presence of eight fungi flora, namely, *Aspergillus repens*, *Trichoderma* spp., *Fusarium verticillioides*, *Lasiodiplodia theobromae*, yeast, *A. niger*, *Fusarium* spp. and *Rhizopus stolonifer*. The frequencies of occurrence of bacteria in the gut compartments of *A. trifasciata* were *Enterobacter* spp.: 83.33%, *Escherichia coli* and *Streptococcus* spp.: 55.56% each, *Staphylococcus* spp.: 44.44%, *Klebsiella pneumonia*: 50% and *Salmonella shigella*: 11.11%, while each of *Serratia marcescens*, *Pseudomonas* spp. and *Micrococcus luteus* had 5.56% occurrence. The occurrence of mycoflora and microbiota species varied in the gut compartments of *A. trifasciata*, indicating the role of these microorganisms in metabolic and other bioprocesses of *A. trifasciata* during digestion and synthesis of complex food substances from the cashew stem substrate [10]. This study would provide basic information for enzymatic studies of *A. trifasciata* with a view to developing an integrated pest management (IPM) protocol for managing the pest in cashew plantations. Since *A. trifasciata* is a cashew stem girdler, a wood-feeding insect at larval and adult stages, it would harbor gut microbial species,

especially fungi and bacteria that are involved in cellulose degradation during metabolism [10].

Most species of the green wood infesting beetles were native forest pests or pests of ornamental trees [9]. However, their damage when they enter the sap wood for pupation often carries over into buildings and is likely to be encountered by pest controllers [7]. The wood of trees although subject to attacks by insects is protected by the bark and trees defensive systems which produce materials such as kino, resin, latex and other substances which prevent insects from entering the wood and in many cases terminate the infestation [7]. Pest controllers engaged in the control of structural pests should have a good working knowledge of termites, the pest species and non-pest or casual species, their habits and of course their control and prevention [8]. Identification of the species is important, as many species require no action and expensive control measures against these destroy client confidence in the pest control industry generally. The dry-wood termites present special problems, particularly since soil barrier treatments are of no value in the treatment of these species. Once a pest controller has given a client all the facts concerning the infestation, it is the decision of the client whether the treatment is done [8]. In South Sudan some termite species in the family of Kalotermitidae and Mastotermitidae attack both green plants such as maize and pigeon peas including mango trees, and also attack houses made of timber, forage and scratch the stems, mango bark, consistently climb upwards and eat deeper into the soft wood [9]. Studies conducted in Australia on termites showed that one house in every five houses had termite attack or had termite history. The study concluded that one should have a better working knowledge of termites, pest species, their habits and of course their control and prevention and added that most pest species of the green wood infesting beetles were natives and were forest pests or pests of ornamental trees. However, their damage when they enter the sap wood for pupation often carries over to buildings and is likely to be encountered by pest controllers. The beetles emerge from timber up to six months after milling [10].

Many insect borers feed and make their homes in the bark, trunks and branches of shade trees and shrubs in Texas [11]. Insect borers belong to several groups including a variety of beetles, moths and horntail wasps. Most of these borers were attracted to weakened, damaged, drying or dead plants and were referred to as “secondary invaders” which also included termites, carpenter bees and carpenter ants [11].

The discovery and first recording of the green wood beetle, *Diastocera trifasciata* in Bor county, was first reported by staff of the Department of Crop Protection, College of Agriculture, Dr. John Garang Memorial University of Science and Technology (Dr. JG-MUST) in the campus, an indication of how concerned the staff were in monitoring their surroundings, including fruit trees [12]. The damage to mango tree branches by *D. trifasciata* that may eventually reduce mango fruit yields should therefore be taken seriously, and a strategy for its effective control be developed and implemented to halt its spread and impact to other areas of high mango production, in the country. The situation therefore, calls for the implementation of the following objectives: (i) to urgently conduct more surveys in areas where mango plants thrive well especially in the Green Belt zone of Greater Equatoria, determine the spread and economic impact of this invasive insect on mango trees; (ii) to start planning to develop an appropriate and sustainable management control strategy at this early stage; (iii) to determine its range of host plants and detect presence of some indigenous predators or parasites affiliated to the beetle in the mango growing environments; (iv) to create awareness among the mango growers, how to recognize damage symptoms observed on infested mango trees and report such symptoms to plant protection unit in the area for early prevention of its spread, and to increase mango productivity for food security and economic prosperity.

2. Materials and Methods

The discovery of this particular beetle *D. trifasciata* was not on a planned normal insect survey usually, conducted to determine what insect species were present in a target area. This was rather like, an accidental event, started by two chemistry professors of Dr. JG-MUST who took keen interest in monitoring the performance of the introduced mango plants to Dr. JG-MUST campus as a source of fruits for the students [12]. The professors observed girdling, brought the specimens to the Crop Protection Department for identification. This was where the department entomologist also took much interest and started surveys in the other mango trees planted around the campus and was then able to confirm that, the beetle was a real invasive pest to mango tree. Pictures of the insect samples collected were taken while maintaining the beetles feeding on some provided mango branches in the laboratory. Images of the beetle were then sent to the International Centre for Insect Physiology and Ecology (ICIPE) in Nairobi, Kenya, for taxonomic identification of the species [13]. Similar surveys were carried out later around Bor county and then extended in Juba town of Jubek state (the central home of the mango plant) [14], through the cooperation of two senior lecturers from Dr. JG-MUST who volunteered and carried out similar observations for the presence of the beetle especially the areas along the White Nile River, inhabited heavily by large mango orchards and mango trees planted at residential areas in Juba town. Results of the surveys confirmed the presence of the beetle in all the surveyed areas in Juba and concluded that *D. trifasciata* beetle could be a real threat to the mango trees in the Republic of South Sudan sooner or later, if not controlled [14].

3. Results and Discussion

The pictures of the beetle below were taken when the insect was girdling a mango twig on September 18, 2015, at Dr. JG-MUST campus, Bor county, Jonglei state [12]. The university is located on an area of 34 ha (lat. 6°22′ N, long. 31°55′ E, altitude 407 m.a.s.l.) and about 4 km, from Bor town, capital of Jonglei state. The town Bor, lies on the eastern bank of the White Nile River and is about 197 km north of Juba, the capital of the Republic of South Sudan. This beetle, in the first literature search, resembles those of the flat faced longhorn borer beetles in the family of Cerambycidae (Coleoptera) [15] *A. trifasciata* (Fig. 1). Immediate identification due to lack of experts was not possible and contacts were made with Dr. Bob Copeland [13] at ICIPE in Nairobi, Kenya for help to look at the images, identify the beetle and give a name. Dr. Copland promptly requested the assistance of Dr. Adlbauer, a world expert on the Cerambycidae who responded positively and identified the beetle as *D. trifasciata*. Dr. Adlbauer [13] in addition indicated that the beetle appeared to be a synonym of *A. trifasciata* and confirmed that this species was once seen feeding on several host trees including those of the Anacardiaceae to which mango belonged and it would not be a surprise to its feeding on the mango twig in Bor county [12, 13].

3.1 Description of A. trifasciata

A. trifasciata is reported to be a species that belongs to the group of the flat-faced longhorn beetle, family: Cerambycidae, subfamily: Lamiinae. The beetle reaches about 5-6 cm (2.0-2.4 in.) in length. The female is slightly larger than the male. The basic

Fig. 1 ***Analeptes trifasciata*** **beetle.**

colour of the body is black with three reddish-orange bands across the elytra (hence the Latin species name *trifasciata*). The black antennae are kept flat along the back and extend beyond the abdomen. *A. trifasciata* of family Cerambycidae has been reported in several African countries [16-18] (Angola, Benin, Cameroon, Central African Republic, Democratic Republic of Congo, Ethiopia, Ghana, Ivory Coast, Kenya, Liberia, Niger, Nigeria, Senegal, Sierra Leone, Togo and recently Uganda), attacking a wider spectrum of trees as host plants in the Savannah environment. Similarly, species *D. trifasciata* which has just been discovered at Dr. JG-MUST on September 18, 2015, in Bor, Jonglei state, and September 11, 2018, in Juba town, Jubek state, is the first recording of the beetle in the Republic of South Sudan [12, 13].

3.2 Feeding Habits of A. trifasciata (Beetle)

Adults and larvae of *A. trifasciata* were reported to feed on the bark and underlying wood of several plants species: *Adansonia digitata*, *Anacardium occidentale*, *Annona senegalensis*, *Ceiba pentandra*, *Eucalyptus camaldulensis*, *E. globulus*, *E. saligna*, *Sclerocarya birrea*, *Spondias mombin*, *Sterculia setigera* and *S. tragacantha*. The infestation of this insect may have devastating effects on cashew (*A. occidentale*) with relevant economic damages [10].

3.3 Description of D. trifasciata (Beetle)

The beetle is generally black in colour, the forewings (elytra) light brown with black colour at both ends (anterior and posterior). The elytra are interrupted with four dots, two on either side of the paired elytra and about 1/3 from the anterior end. This is followed by a black band about 2/3 from the anterior running across both pairs of elytra and followed by 1/3 light brown portion of the elytra, towards the black portion at the end of the elytra. The two dots at the anterior end exist but the black band below is interrupted by black dots in the middle. The two beetles bear different spots on the elytra but belong to the same group of beetles and appear different in colour from that of *A. trifasciata* family Cerambycidae.

3.4 Comparative Analysis

Comparative analysis of the two beetles was carried out as in Table 1.

Table 1 Comparative analysis of two beetles (smaller and bigger) in sizes.

Specimen A	Specimen B
Body small in size Head: 4 mm Neck (thorax fused): 6 mm Antenna has nine segments and ends beyond the abdomen Wings: A pair of fore-wing (yellow elytra) hind wing transparent and white-creamy Leg: tarsus (three segments) Total length of the body: 26 mm Yellow part from anterior to posterior: 12 mm Yellow part towards the posterior end: 6 mm	Body big in size Head: 4 mm Neck (thorax fused): 7 mm Antenna has nine segments and ends beyond the abdomen Wings: A pair of fore-wing (yellow elytra) and hind wing whitish and transparent Leg: tarsus (three segments) Total body length: 28 mm Yellow portion from the anterior: 13 mm Yellow portion towards the posterior end: 5 mm
	

3.5 Feeding Habits of D. trifasciata in Mango

The beetle positions itself horizontally on top of the branch and starts girdling (cutting ground) the branch [15-18]. The damage caused to the mango twig results in whitish exudes later turning to brownish sweet liquid. This sweet brown liquid attracts bees, bumble bees and wasps to feed on. Although the sap appears at first colourless, it however slowly turns into brownish and sticky substance. Figs. 2 and 3 demonstrate the feeding habit of *D. trifasciata* beetles observed in mango trees grown in Bor county, while Figs. 4-7 are from Juba, Jubek state.

3.6 Discussion

The species belong to the selected *A. trifasciata*. This is a synonym for the scientific name *D. trifasciata* (Fabricius, 1775). According to the literature, there are 13 synonyms. The scientific classification of *A. trifasciata* is as follows:

Kingdom	Animalia
Phylum	Anthropoda
Class	Insecta
Order	Coleoptera
Suborder	Polyphoga
Superfamily	Chrysomeloidae
Family	Cerambycidae Latreille 1802
Genus	*Diastocera*

Cerambycidae Latreille, 1802 [19] stipulated that longhorn beetles belong to family Cerambycidae also

Fig. 2 *Diastocera trifasciata* girdling mango twig.

Fig. 3 *D. trifasciata* attacking mango branch on Sept. 18, 2015 in Bor.

Fig. 4 *D. trifasciata* beetle cutting down mango branch on Sept. 11, 2018 in Juba, Jubek state.

Fig. 5 Beetle feeding on mango twig in Juba.

Fig. 6 Beetles search feeding sites.

Fig. 7 Beetle looking for feeding site.

known as longhorned or longicorn beetles or longicorns. Cerambycidae is a cosmopolitan family characterized by extremely long antennae often longer than the beetle's body. However, some members of the family have short antennae, e.g., *Neandra brunnea* and this had made it difficult to distinguish such species from related beetle families as the Chrysomeloidae. Family Cerambycidae, comprises over 26,000 species and more than half are from the Eastern Hemisphere, several of which are pests. The larvae, known as the round-headed borers, cause devastating damage to either living trees or untreated lumber or occasionally to wood in buildings. A number of species mimic ants, bees and wasps though a majority of species are cryptically colored. This large family (Cerambycidae) had been classified by some authorities into many subfamilies, or sometimes split subfamilies off as separate families entirely, e.g., Disteniidae, Oxypeltidae and Vesperidae. This has caused some instability and controversy regarding the constituency of the Cerambycidae. Other taxonomists reported that, there were few truly defining features for the group as a whole at least as adults but some species groups might lack any given feature and therefore, constitute a taxonomically difficult group as relationships of the various lineages were still poorly understood [19-21].

4. Conclusions and Recommendation

South Sudan is blessed and bestowed with abundant natural resources: fertile arable soils for agricultural and forestry products, huge number of domesticated livestock, cattle, sheep and goats, fisheries, a variety of wild life species, myriad of insect fauna and flora, and the largest and huge fresh water reservoirs "Sudd". Unfortunately, the nation lacks patriotic nationals, equipped with knowledge to effectively exploit and manage these natural resources. After the country achieved the long awaited independence in July 2011, through a popular referendum enhanced by the Comprehensive Peace Agreement (CPA) between the Sudan and the Sudan Peoples' Liberation Movement/Army (SPLM/A, in 2005), Government of South Sudan forgot initiating projects to develop these resources. On the contrary, citizens locked themselves into series of tribal conflicts, cattle raiding, looting, land grabbing, purchase of expensive vehicles like the "V8" and maximum corruption in public offices.

The only option needed now, is to engage seriously on capacity building of the South Sudan academia in post graduate studies in the universities and research centers in all fields of specializations. This will generate the knowledge bank for engaging aggressively to explore and manage these resources for maintaining a sustainable, vibrant economic growth for better livelihoods and prosperity of its citizens as follows:

(1) The oil investment funds should be redirected partially to fund the exploitation of the natural resources as oil may run out any time soon;

(2) The government should avail sufficient funds to its public universities, installation of the research centers in the country to give enough room for capacity building, raise the salaries of the staff similar to those observe in other institutions of higher education as motivating incentives;

(3) Attract investors to develop projects in agriculture, forestry fisheries and the live-stock sectors;

(4) The government and warring groups should commit themselves to realize the signed peace, stop the tribal wars and embark on food production for achieving food security in South Sudan.

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