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Role of *Elaeidobius kamerunicus* as an Economic Arthropod Pollinator in Oil Palm Cultivation: A Review

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Abstract

Demand for oil palm is anticipated to rise due to it uses globally. Factor responsible for an increase in production per unit area should be address to meet this demand. Research on the fundamental factors affecting decrease in oil palm fruit set and palm oil yields is alarming by prevailing declines in oil palm fruit set, palm oil yields and the oil yield gap. Since 1980s the oil palm pollinator Elaeidobius kamerunicus has been widely known as the most primary effective pollinator. It is positively related to Elaeis guineensis with fluctuating degree of merits and a high acceptability level of oil palm fruit set with high oil yield returns, signifying efficient pollination as a result of adequate kamerunicus weevil population. However, in recent times, researchers have reported decline in its proficiency as the main pollinator.

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It has further been questioned if the existing populations of these weevils are sufficient to maintain excellent fruit set for better productivity. Research has proven a decline in the population of this pollinator, especially the male kamerunicus. High rainfall and temperature, application of chemicals and natural enemies could be the main reasons for decline in the Elaeidobius kamerunicus population. It could be suggested that further research be done in addressing the decline in Elaeidobius kamerunicus population.

Keywords: *Elaeidobius kamerunicus*; Oil Palm; Economic Pollinator; Pollinator Efficiency; Population Density.

1. Introduction

The Arecaceae, also known as palms, are stem-less family, tree-like monocotyledonous plants that hold considerable importance for humans and broader biodiversity, particularly in tropical regions [1]. The *Elaeis guineensis*, is indigenous to West Africa and is arguably the most significant palm species in agriculture globally [2]. The tropical ecosystems foundation species are palms, particularly found indoors of the tropical rain forests and across Africa, serve as the most imperative attributes of various vegetation types [1]. Oil palm is a unisexual inflorescences producer and is basically entomophilous, or pollinated by insects [3]. (Daud and Ghani, 2016). According to Hardy *and his colleagues* [4], the pollen produced by the male flowers is then transmitted to the female flowers by the wind (aemophil) or by different insects, including weevils (entomophil).

The fruits of oil palm are accessible throughout the year and have functioned as semi-wild food supplies in traditional communities for over 70000 years ago [2]. The oil palm plant holds considerable importance for local populations and broader biodiversity in its native regions [2]. Approximately 75% of food crop species worldwide depend at least partially on pollination, making it an essential component of the development of both food and non-food crops [5], because pollination impacts crops especially angiosperms, comprised of biofuel plants and pollination is economically significant for agriculture and global food security.

However, a number of reasons, including pesticide exposure, land use practices, climate change, habitat loss and diseases are contributing to the global decline in pollinator populations, which has a major effect on agricultural productivity. Decreased pollination services may result in poorer crop yields, inferior fruits and seeds, and possible ripple effects on biodiversity and ecosystem operatives [5]. In recent years, crop pollination has become jeopardized [5], as pollinator populations and their efficacy in pollinating crops have diminished due to a confluence of factors, including habitat loss resulting from human activities such as agriculture and urbanization, which eliminate critical nesting and foraging habitats [5].

The most efficient oil palm pollinator weevil [Elaeidobius kamerunicus (EK)] population density and its efficiency on oil palm fruit set is envisioned to explore in this chapter. According to Swaray *and his colleagues* [6], in their field research with the use of experimental biparental progenies previously reported in their publication, through their consistent analysis, the results found low performance of the biparental D×P progenies and their origins in the preceding experiments for oil palm fruit set. This suggested further study on the population density and efficiency of *E. kamerunicus* in relation to oil palm fruit set. Pollination is key and is an inevitable process in oil palm which can be effectively done by *E. kamerunicus.* Both the *Elaeidobius* *kamerunicus* and the *Elaeis guineensis Jacq* are endemic to Africa. Despite this, the *species guineensis* has been widely cultivated outside of its natural region, and its pollinator was also acquired and introduced to novel environments [7]. Majority of information on oil palm and its pollinators is not indigenous, and there is little material of African provenance reflecting on their activities in Africa, which is cause for concern [7].

The reproduction and survival of several species of flowering plants depend on pollination, which is a crucial ecological service [8]. For sustained crop production to occur, there must be a mutualistic, co-evolutionary connection between plants and animals [9]. It is impossible to overstate the significance of pollination and insect pollinators in guaranteeing an economically viable oil palm production and, consequently, appropriate fruit set and desirable yield in oil palm [10-11]. In relations of satisfactory fruit set and enhanced output, Indonesia and Malaysia, which control majority of global palm oil production and trade, as well as other non-African palm oil producing nations, have been known to gain from the introduction of pollinating insect species [12].

Malaysia is the second largest palm oil producing country after Indonesia and considering her as an example, the *E. kamerunicus* effectiveness is thought to have reduced in oil palm plantations [6]. This has led to very low oil palm bunch fruit set values across a variety of plantations [13]. Low bunch development, low fruit production, and bunch failure may result from incomplete pollination [14]. The efficiency of pollination is influenced by a number of variables that control insect behaviour, including environmental conditions, size of the weevil, quantity, aroma (estragole) produced, blossom colour and exposure to the male inflorescences [15]. In the earlier research of Prasetyo *and his colleagues* [15] shown that the existing drop in fruit set was due to the low population density of *E. kamerunicus*. In a similar vein, Frimpong and Adjalo [16] and Sisye [17] observed that the low fruit set in oil palm has been caused by a lack of pollination weevil availability. We proposed that *E. kamerunicus* population density differs between various oil palm hybrids in light of the current drop in oil palm output. The *E. kamerunicus* populations of various biparental D×P hybrid palms grown on deep peat soil were compared in the studies of Swaray *and his colleagues* [6-18] and reported a significant difference in the *E. kamerunicus* population density due to the full-bodied aroma produced by each progeny during anthesis. Swaray *and his colleagues* [6] further reported that among the D×P hybrids, the population of the male *E. kamerunicus* was lower than the population of the female *E. kamerunicus* and the male has the potential to carry more pollen than the female as a result of its hairiness.

In recent years, however, a large proportion of parthenocarpy fruits have been produced and reported as a result of incomplete pollination and ineffective pollinator operation [19-6]. Therefore, it is essential to research pollinator species behaviour for improved pollen transfer and the improvement of oil palm fruit set [20]. There is a direct correlation between the pollinator weevil population abundance and the development of the oil palm fruit set [21]. To entice the *E. kamerunicus* pollinator for pollination, both male and female inflorescences release a distinct aniseed aroma [22-23].

There is little material of African provenance commenting on the actions of oil palm insect pollinators in Africa, particularly West Africa, despite the benefits of these pollinators having been reported in literature for these nations [7]. However, Setyawan *and his colleagues* [24], reported that the decreased in the weevil prolificacy brought on by incorrect acaricide and insecticide treatment.

More research is required to understand the role played by insect pollinators, how this can be explored, and factors that encourage or affect their activities on oil palm within the continent in order to address this observation and sustain industries that depend on oil palm products. The female and male inflorescences of oil palm are produced sequentially in form of a cycle and the two dissimilar inflorescences do not overlap at the time of sexual maturity and therefore a transfer of male pollen grains is required for pollination [21]. Oil palm is pollinated by both wind and insects, though the latter is more common and reliable.

2. Oil palm and its inflorescence production

A significant plantation crop native to Africa is oil palm and is also widely grown in many other nations outside of its original continent. It is known for its high-yielding performance that generates more vegetable oil per unit of land when compared to other oilseed crops [25]. It can extract oil from both the fruit's mesocarp and the kernel. In order to stake its entitlement as the world's greatest significant and major basis of vegetable oil commodity [26], it is known to approximately account for 35–36% of vegetable oil production oil supply worldwide [27]. In Sierra Leone for example, oil palm is now the leading major economic crop due to its outstanding uses in everyday life followed by cocoa as the second most essential cash crop.

The potential quality of inflorescence of oil palm has been cited to be directly determined by the leaf initiation rate as a single inflorescence originating in each leaf axil [28]. Normally, grown palm bears 45 to 50 unopened fronds in varying phases of development with an opened leaf of 32 to 48 leaflets and the palm age determines the leaf initiation rate.

The male inflorescence (Figure 1) is made up of 100 to 300 spikelets and each spikelet carries 400 to 1,500 flowers in the length of three to four mm [29]. The newly developed inflorescence normally takes nearly two years to attain the central spear from initiation. A male flower bears several cylinder-shaped spikelets of 15 to 25 cm and a peduncle of 40 cm in length, forming an ovoid body shape. The male flower contains a rudimentary gynoecium, six anthers of tubular androecium and six perianth parts with connate base. The weight of the pollen grains produced when shed over two to four days from each flower is approximately 30 g and the palm is primarily insect-pollinated [30]. According to Reis *and his colleagues* [31], insufficient pollen quality or number may also hinder effective crop pollination, resulting in diminished yields.

Figure 1: Oil palm male inflorescence: (A) Before anthesis, (B) During anthesis, (C) After anthesis

The female inflorescence (Figure 2) is similar in structure to the male, except the female peduncle is thicker and shorter with a length of 20 to 30 cm. The female contains 150 spikelets of 6 to 15 cm length and five to 30 flowers borne on each spikelet subtended in the form of a sharp spine by a bract [29]. The female flower ends in shallow terminal spines and to each flower, there are two rudimentary masculine flowers, a three lobed and sessile stigma. As the female flower does not open altogether at the same time, there is always an interval period between the opening of the first flower and the last for a duration of about seven days and its receptive period is 36 to 48 hours. The number of spikelets and flowers of both sexes increases with palm age and within 10 to 12 years after planting, the maximum peak is reached followed by a decline.

Figure 2: Oil palm female inflorescence: (A) During anthesis, (B) After anthesis

3. Pollination in oil palm

Plant breeding approaches take advantage of the pollination process of how a flowering plant is pollinated. The act of pollen grains transfer from the anther of a male flower to that of the female stigma is called pollination. Therefore, pollination entails two general approaches (self-pollination and cross-pollination). The self-pollinated plants are homozygous at gene loci, while cross-pollinated plants produce hybrids that are heterozygous, phenotypically uniform for many gene loi [32]. From the same species, the transfer of pollen between flowers enhances seed production, which involved abiotic (water and wind) and biotic (birds, insects and other mammals) pollinators. In flowering plants, the biotic pollinators account for more than 80% for every pollination [33].

Consequently, for many crops, insect pollination is vital [34] and for every pollination process that occurs in flowering plants, more than 80% are done by biotic pollinators [35]. The *E. kamerunicus* is extremely dependent on spikelets of the oil palm male inflorescence where they breed, feed and animate [20]. The weevil is an oil palm-specific host because it does not reproduce on any other species of plants. The soft portion of the oil palm male flowers for egg-laying and pollen production is consumed by the *E. kamerunicus* pollinator weevil [36]. Its visitation depended on aroma produced by the male inflorescence ascribed as estragole or P-methoxyally benzene [22]. In oil palm the female and male inflorescences emit sequentially in the form of a cycle and two dissimilar inflorescences do not overlap at the time of sexual maturity and therefore transfer of male pollen grains is required for pollination. The proportion of fruit set is significantly associated with the population density of the pollinating weevils [21].

In young oil palm plants, entomophilous pollination is considered as the utmost significant method. According to Swaray *and his colleagues* [18], the *E. kamerunicus* effectiveness is more manifested in shorter and medium hight palms than taller palms, which is more advantageous for wind pollination. Nonetheless, this procedure strongly depended on diverse factors as a determinant for insect occurrence which included but not limited to flower colour, insect size, aromas of male inflorescence, number of hairs and exposure as well as weather conditions [37].

4. Oil palm pollinator (*Elaeidobius kamerunicus*) and its life cycle

The pollinator *E. kamerunicus* Faust belongs to the kingdom Animalia with Phylum Arthropoda which belongs to the class *Insecta*, family Curculionidae and the order Coleoptera, and is closely related to the male inflorescences of *Elaeis guineensis* palms [20]. The weevil *E. kamerunicus* is the most significant oil palm pollinator in Asian nations especially Malaysia and Africa is no exception (Figure 3). The body structure of *E. kamerunicus* is divided into the abdomen, thorax with a pair of wings (membranous thin wings and elytra 18 wings) and head [38]. The average adult *E. kamerunicus's* length ranges from 1.8 to 4.0 mm in the dark-brown to black [39]. The wing cases of male *E. kamerunicus* has small tubercles, a short rostrum, are hairy, and are normally wider (3-4 mm), whereas the wing cases of females lack small tubercles, have a longer rostrum, are less hairy, and are smaller, measuring only 2-3 mm [40].

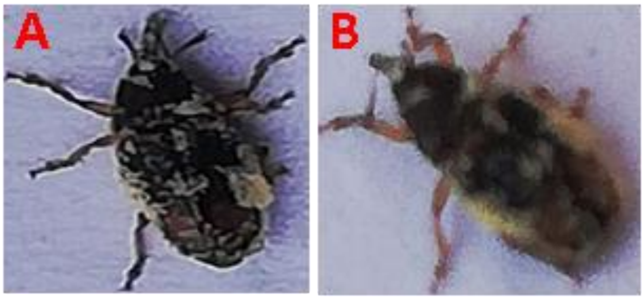

Figure 3: *Elaeidobius kamerunicus* from anthesising male inflorescence of oil palm (A) Female (B) Male

This weevil undergoes complete holometabolous during their developmental stages, and the holometabolous occurs within 10 to 25 days and amid 15-days and 17-days higher longevity [11]. The *E. kamerunicus*'s life cycles include the egg to larvae (larva stage one, two, and three), adulthood (pupa development, and imago) stages. For the reason that, it cannot reproduce on any other species of plant, the weevil only hosts oil palms [6]. The *E. kamerunicus* pollinator weevil feeds on the soft part of the oil palm male flowers used for egg-laying and pollen production [36]. According to Kouakou *and his colleagues* [21], (2018), the pollinator weevil population abundance is closely related to the percentage of oil palm fruit set.

5. Introduction of *Elaeidobius kamerunicus* in Malaysia and its potential efficiency

The roll of insects in oil palm pollination as a vital operation was not visualise until the late 1970s according to evidence in literature [33]. As a result, it was widely believed that the oil palm was only wind (anemophilous) pollinated [41]. (Robins, 2021). Nonetheless, in order to achieve a reasonable yield, aided pollination was required due to the persistently observed poor fruit-set yield [42].

This misunderstanding was finally dispelled by Syed's work in Malaysia and Cameroon in the late 1970s and early 1980s, respectively. Insects were found to be necessary for pollination in addition to wind [43]. According to Haran *and his colleagues* [20] and Corley and Tinker [44], oil palm was really mostly pollinated by insects, and the contribution of wind to pollination, particularly during the wet season in Malaysia and Cameroon, was minimal. After the introduction of *E. kamerunicus*, the main insect pollinator of oil palm in Cameroon, into Malaysia, aided pollination by humans was eventually discontinued, saving money and labour and the run-down natural pollination problems were addressed [45]. This led to improved fruit-set, increased bunch weight, and increased fruit output [20]. According to Syed [45], reported that in 1981, 20 to 30% of fruit set yield was realized in Malaysia and 30% cost of production in manual pollination was reduced and approximately 43% of the kernel to bunch ratio was attained [46], prior to its efficiency. A similar weevil was introduced to Indonesia in 1983, and as a result, the proportion of sterile fruit in commercial plantations reduced to about 36% [38]. The introduction of this weevil has significantly increased yield in numerous palm plantations around the world [47]. In previous findings, Ponnamma [48] revealed that a 36.9 to 78.3% bunch fruit set was achieved. Gintoron *and his colleagues* [49], affirmed that after the introduction of *E. kamerunicus* in oil palm plantations, the achievement of higher yield of fresh fruit bunches have been recorded. This indicated that the relationship between crop production and *E. kamerunicus* population was exemplary compared with several other crop species [50-51].

According to Mariau *and his colleagues* [52], twenty species belonging to *genus Elaeidobius* were submissive to oil palm flowers. They had dissimilar pollinating powers of which four species (*E. kamerunicus, E. singularis, E. subvittatus and E. plagiatus*) were eminent and at the time of pollination, they provide the biggest share. The *E. kamerunicus*, and *E. plagiatus* were the most active species [52]. Based on the impact of climatic factors, their population force differed in a very significant mode in time and space. On this note, for various crops, pollination by specific pollinating organisms is vital [53]. Female and male flowers bear on distinct inflorescences for the transfer of pollen by insects or wind [54]. Oil palm production in Malaysia relied primarily on wind and labour-intensive transfer of pollen by humans as mechanisms for pollination even though *Pyroderces* sp. (*Cosmopterygidae*: *Lepidoptera*) and *Thrips hawaiiensis* (*Thysanoptera*) are natural Malaysian oil palm pollinator weevils, even though these weevils were proven to be ineffective in nature as oil palm pollinators [55]. Based on larger pollen loading size, and pollen grain germination quality and its influence on the position rate, the EK is presently the most effective oil palm pollinator species [21].

6. Relationship of *Elaeis* species and *Elaeidobius kamerunicus*

The effectiveness of pollination in *Elaeis species* depends on wind and coinciding with the monoecious nature of the palm [42]. There is a mutual relationship between the host plant and the *E. kamerunicus*. The brood sites are the male inflorescences and the inflorescence of the female is pollinated by *E. kamerunicus*. This weevil is extremely dependent on spikelets of the male inflorescence where they breed, feed and animate. Its visitation depends on the aroma produced by the male inflorescence [22], while the female flower produces a similar aroma, but weaker when compare to the male flowers, with the female inflorescence being visited by accident.

The adult of this organism can survive on Cocos nucifera flowers for two weeks and one week only on Eugenia aqueous flowers but not oviposit, even though it is precisely for oil palm [10].

7. Prior studies on *Elaeidobius kamerunicus* as an efficient pollinator

Changes in the insect population are responses due to several factors, including rain level, humidity, plant population, oil palm species and quantity of male inflorescences [42]. Daud and Ghani [3], reported that a total of 60,608 *E. kamerunicus* pollinator weevils were collected in the Lekir oil palm field, Batu, Perak. The pollinator force means number per hectare (ha^{-1}) was between 652 to 1,281 with the highest in February (1,281 weevil's ha^{-1}) and the lowest in January (652 weevils ha^{-1}) in eight years old palms. In five-year-old palms, the pollinator force means of 3,095.2 to 19,126 recorded the highest in February and lowest in October. Syarifah and Idris [56], recorded pollinator mean number per spikelet ranged between 26.12 per spikelet in December as the highest and 21.2 per spikelet in November as the lowest for eight years old palms and 13.5 to 54.1 per spikelet with the highest recorded in January and February recorded the lowest for five-years old palms.

Another study carried out by Yue *and his colleagues* [57], stated that during the day one with 25% blossoms opened, few adults *E. kamerunicus* pollinators were found on the spikelet of male inflorescences. Following day two of anthesis with 50% florets opened, the population of adult *E. kamerunicus* increased to a mean number of 14 $spikelet^{-1}$. On day three of anthesis, when the blossoms were completely (100%) opened, adult *E. kamerunicus* pollinators were mostly profuse on the male spikelet with a maximum mean number of 33 $spikelet^{-1}$. Both the spikelet and the weevils were covered by the golden yellow pollen grains. On the fourth and fifth days of anthesis, the population of the adult *E. kamerunicus* declined, as a result of declining pollen. On the six day, no adult *E. kamerunicus* were observed and the male spikelet basal parts began to decay. Based on the validation by Swaray *and his colleagues* [18] and Basri and Norman [14], a high pollinator population of *E. kamerunicus* was not advantageous because it led to a decrease in fruit set. According to Basri and Norman [14], for good pollination, 15 to 30 normal weevils' $spikelet^{-1}$ were required per male inflorescence, and about 4,000 to 30,000 weevil's ha^{-1} population depending on the phase of anthesis of the male inflorescences. Rizuan *and his colleagues* [59], reported that about 2,883 weevils ha^{-1} was the actual population force with a maximum population mean of 10,658.74 weevil's ha^{-1}. The total mean number of *E. kamerunicus* per spikelet was 20 weevils. The maximum population of the pollinator insects was mostly recorded in September (20 weevils' $spikelet^{-1}$) and minimum population level in May (10 weevil's $spikelet^{-1}$).

Rizuan *and his colleagues* [58], further stated that to achieve more than 60% fruit set, then the fruit per bunch ratio must be observed. Nevertheless, non-significant was found between pollinator insect $spikelet^{-1}$ and *E. kamerunicus* ha^{-1} with the percentage of fruit set. The fruit set percentage performance was not meaningfully impacted by the pollinator population and pollinator mean per spikelet. Donough *and his colleagues* [59], projected that 60% fruit set can be achieved through the assistance of 20,000 *E. kamerunicus* pollinating insects ha^{-1}. Rizuan *and his colleagues* [58], findings further revealed that to increase the *E. kamerunicus* population in palm plantations, dry season with 120 mm rain $month^{-1}$ or less was reported as favourable conditions. There was no decline in pollinating efficiency detected even though throughout the dry season, a decline in the *E. kamerunicus* population was observed. Rizuan *and his colleagues* [58] and Zulkefli *and his colleagues* [60], reported that limiting *E. kamerunicus* pollinating assistance associated with rainfall greater than 500 mm may result in a low fruit set. The *E. kamerunicus* although considered as the most effective oil palm pollinator, does not have the features adapted to rainy circumstances. Additionally, a low fruit set has been associated with pollen incapability, poor pollen viability, failure of embryo development due to poor fertilization and dysfunctional anthesis. Woittiez [28], also reported that fruit set was primarily determined by pollination efficiency. The pollinating effectiveness has been bottled-up as a consequence of an increase in precipitation, even though a satisfactory population of *E. kamerunicus* weevil was established. Kouakou *and his colleagues* [21], reported that the abundance of pollinator weevil population was primarily influenced by sunstroke and the numeral of rainy days. The availability and accessibility of male inflorescence and the number of precipitations appeared to be the main factors in the willpower of the pollen load on *E. kamerunicus* [3]. According to Gintoron and his colleagues [5], the fruit set is determined through pollen load by *E. kamerunicus* pollinators but not actually the *E. kamerunicus* population density on the spikelets of the male inflorescence. The precipitation levels which ranged between 200 to 300 mm/month did not suppress the activities of the pollinator insects [50]. Daud and Ghani [3], stated that as the palm grows taller, the wind is one of the agents of pollen carrier, and play more significant roles than the weevil pollinators themselves. The study on the relationship between monthly population density of *E. kamerunicus*, fruit set ratio and fruit-to-bunch in biparental progenies and the need to evidence the understanding of oil palm pollinators and their activities were reported in prior study by Swaray *and his colleagues* [6].

9. Efficiency declines in *Elaeidobius kamerunicus*

There has been a continuous diminution in the oil palm fruit set as being reported (Figure 4). Prasetyo *and his colleagues* [15], reported that the oil palm bunch fruit set has recently declined as a result of a decrease in *E. kamerunicus* population. For Malaysia's oil palm industry, the most challenging year was 2018 with a record of low production of fresh fruit bunch (19.52 t ha^{-1}), followed including its prices and export earnings [61]. Regardless of the unremitting expansion of oil palm plantations across the country and efforts by the Malaysia Palm Oil Board (MPOB) in addressing their vision and mission statements, there still exist inadequate quantities of fruit set in palm plantations. According to Latip *and his colleagues* [62], the yield output of oil palm has declined recently with several contributing factors and most alleged that it's could be the declining population of the *E. kamerunicus*. Malaysia and other oil palm growing countries in Africa such as Sierra Leone are no exception. The 4.5 t ha^{-1} of the oil palm fresh fruit bunch represented the best harvest and this was smaller than the 18 – 30 t ha^{-1} as the optimum of fresh fruit bunch and this can be characterized as an inefficient pollination process of inadequate pollinators [63]. With the current declining in fruit set and oil yield, it is empirical that the alleged decline in EK population and its efficiency performance was investigated in diverse D×P biparental progenies with divergent climatic factors.

Figure 4: Oil palm fruit bunches and categories of fruits (A) Inadequate fruit bunches, (B) Adequate fruit set and (C) Parthenocarpy fruits

10. Decline in *Elaeidobius kamerunicus* population

The dynamics in pollinator insect populations varies based on weather conditions such as high rainfall and temperature and palm species [42]. Dhileepan [46], confirmed that the *E. kamerunicus* species was well-adapted during the rainy season. Syed [45], proved that at the time of the rainy season, the population force of *E. kamerunicus* diminished. Due to its effectiveness in pollination, during cloudy days or wet season especially at the time of rainstorms, this organism turns out to be less active [45]. According to Yusdayati and Hamid [64], the application of pesticides affects the population force of *E. kamerunicus*. This simply implies that a reduction in bunch fruit set may rise as a result of a decline in the population and pollinating deeds of the weevil.

Figure 5: Natural enemies of *Elaeidobius kamerunicus* towards its population decline (A) Grazed spikelets of an unopen inflorescence by rodents (B) Predator bird (Circled) (C) Spider web traps

The decline in *E. kamerunicus* population was noticed to be adversely affected by natural enemies which included but not limited to rodents/rats, birds and spider webs as the most compelling evidences (Figure 5) are also some of the factors associated with its population decline. Earlier studies evidenced that the larvae of this important and efficient oil palm pollinator weevil had been used as feed by predators like *Pycnonotus goiavier*

(Yellow-vented bulbul) bird species, ants and rats [57-65]. Increase in *Rattus tiomanicus* population caused extremely enormous damage to oil palm inflorescences [66].

After a decade preceding of the introduction of *E. kamerunicus*, there were reports regarding the incredible decline in fresh fruit bunch yield causing dropped in annual income of several billion dollars [67]. Of late, Teo, [54], affirmed that there has been low fruit set in Peninsular Malaysia and Sarawak oil palm plantations as a result of poor pollination. The reduction in oil palm yield had been associated with the decline in *E. kamerunicus* populations and its pollination efficiency and perhaps the reduction in its population force and pollination effectiveness was due to unfitting application of pesticides, disease and contagion, predation and parasitism [64-13]. Consequently, the use of pesticides such as Cypermethrin and Chlorantraniliprole for pest control in oil palm were stopped as they impeded *E. kamerunicus* pollination activities. In Malaysia's oil palm ecology point of view, the potential of natural predators such as wasp, spider, dragonfly species, ant, bug, bird, rat were regarded as enemies which target *E. kamerunicus* weevils. These menaces might have indirectly or directly transformed and influences of *E. kamerunicus* activities [67]. In determining the predatory insects' abundance in oil palm plantations, the height of oil palm plants certainly played a key role [68].

Gintoron *and his colleagues* [5] reported that spikelets served as home-based, breeding sites and important food sources for the EK. The larvae and pupae including eggs of *E. kamerunicus* which live within the inner parts of spikelets could be uncourtly consumed when rodents grazed on spikelets of the male inflorescences. Reis and his colleagues [31], similarly reported that rats (*Rattus tiomanicus*) were found feeding on the pollinator's weevil larvae on the postanthesis inflorescences of the males. Once the population of *Rattus tiomanicus* increases in oil palm plantations, the impairment to oil palm inflorescences is tremendously huge [67]. Amit *and his colleagues* [65] also reported that the bird species, *Pycnonotus goiavier* consumed more than 80% of *E. kamerunicus* in oil palm plantations in Malaysia.

11. Pollen theft during oil palm pollination

McCall *and his colleagues* [69], defined pollen theft as the product of interactions that occurs between the structure and development of host plants floral and the potential thief. Pollen theft is prevalent in specialized flower plants than generalized flower plants. This is due to the unique floral structures that may impede efficient pollination employing generalist floral guests. Victors like honeybees are habitually incompetent in pollination of oil palm, they are therefore considered as pollen thieves due to their frequent visitations to oil palm florae. Also, added interaction is nectar theft, whereby they obtain nectar without pollination and diminish of female plant fitness is as a result of nectar robbing [70]. According to Meléndez and Ponce [42], male flowers are primarily visited by bees for pollen and they did not contribute to pollination directly. *Diptera* (true-flies) could as well be found on the inflorescences of oil palm, yet, they play no role in oil palm pollination [71-72].

12. Conclusion

In conclusion, the *E. kamerunicus* has been widely known as an efficient oil palm pollinator even in the mist of Africa. Oil palm fruit set increases due to its efficiency since its introduction in other part of the word. However, its population decline has been detected by many researchers causing low fruit set, resulting to lower fruit bunch weight, with an increase in the oil palm parthenocarpy fruits. Environmental factors, use of chemicals for the control of ailments and pests, and natural enemies of this important oil palm pollinator *E. kamerunicus* has consistently contributed to its population decline. It was further reported that the decline is more attributed to male *E. kamerunicus* population which has more potential to carry pollen to the female inflorescence of oil palm. Therefore, for future improvement in oil palm fruit set, it could be necessary to bring solutions to the factors responsible for the decline of *E. kamerunicus* population especially the male *E. kamerunicus.*

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13. Declaration of competing interest

The authors declare no conflict of interest.

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