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Effect of Lepidopterous Stemborers, *Busseola fusca* (Fuller) and Chilo Partellus (Swinhoe) on Maize (*Zea mays* L) Yield: A Review

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Abstract:
Cereals are very important crops grown in Africa for human consumption. Our review confirms that of the various insect pests attacking cereals crops in Africa, lepidopteran stem borer,B.fusca and C.partellus are by far the most injurious causing maize yield losses in many African countries.B. fusca is indigenous to Africa and C.partellus invaded the continent from India. Severe damage is caused by the larvae that feed on the plant from early stage up to maturity causing a devastating impact on maize yield. Increased damage in young plants is due to tenderness of leaves and stem since aged and toughened leaves are unsuitable for newly hatched larvae.Their distribution follows a define pattern with B.fusca dominating the high elevation (> 1200 m) while C.partellus is most abundant and widely distributed species occurring at all sites, but predominantly in the low elevation (<600 m). C.partellus distribution is highly influenced by altitude and moisture gradients. This article is an attempt to summarize the status of knowledge about economically important cereal stem borers in Africa with emphasis on their distribution, host plants, general damage and larval behavior, yield loss in Africa, pest management and conclusion. B.fusca and C.partellus are given special attention as they are most important pests of maize in Africa.

Keywords: *Chilo partellus, Busseola fusca, effect on maize yield*

1. Introduction

The majority of people in Sub-saharan Africa have maize as their staple food [50].Its production is hampered by the larvae of the lepidopterous stem borers *B.fusca* and *C.partellus* [22-49]. They are generally considered to be the most damaging insect pests of maize and sorghum in Africa. Their distribution, relative abundance and pest status are expected to vary with environmental conditions [22]. *B.fusca* and the exotic *C. partellus* are the dominant species in East Africa. *C.partellus* had proven to be a highly competitive colonizer in many areas of eastern and southern Africa, often becoming the most injurious stem borer and displacing native species [31]. For example, studies in Coastal Kenya showed that *C.partellus* displaced the indigenous stem borer *Chilo orichalcociliellus* (Lepidoptera: Crambidae). Similarly, in the eastern highveld region of South Africa, *C. partellus* partially displaced *B.fusca* over a period of 7 years. Within two year, it became the predominant borer; constituting 90% of the total stem borer populations. One of the possible reasons for the replacement of the indigenous species is that hibernating larval populations of *C.partellus* terminate diapause and emerge a month earlier than*B.fusca* [22]. In addition, the life cycle of *C.partellus* is three weeks shorter than that of *B.fusca,* which gives it a further competitive advantage because of its higher potential rate of an increase. *B.fusca* is the dominant stem borer species in high-potential zones (high tropics, moist transitional zone and moist mid-altitude) and the exotic *C. partellus* dominate smallholder farms in low potential zones (dry mid altitude, dry transitional and lowland tropical zones) [25]. *C.partellus* was reported in India as one of the most destructive pests of maize and sorghum, and most important at altitudes below 1500 m above sea level [22]. [25]Conducted a survey in 1999 and 2000 and reported that *C.partellus* widened its distribution from 500-1700 to 1030-1900 m above sea level whereas *B.fusca* was recorded between 1030-2320 m above sea level [24]. In Ethiopia, *B.fusca* and *C.partellus* are considered as the most damaging insect pests of cereal crops. In Zimbabwe, *B.fusca* and *C.partellus* are also considered important stemborer species that contribute significantly to yield loss of cereal crops [16- 15-40].This paper reviewshost plants, damage and yield losses caused by stem borers on maize.

2. Distribution of *Busseola fusca* and *Chilo partellus*

2.1. Chilo Partellus (Swinhoe)

The spotted stemborer, *C.partellus,* originated in India-Pakistan region [10]. In Africa, *C.partellus* is found in most Eastern and Southern Sub-saharan countries, including Botswana, Cameroon, Eritrea, Ethiopia, Kenya, Malawi, Mozambique, Somalia, Sudan, South Africa, Lesotho, Swaziland, Tanzania, Uganda, Zambia, Zimbabwe and the Islands, Comoros and Madagascar [21-55-10]. *C.partellus* was first recorded in Malawi in 1930 and is mainly found in areas with an altitude below 900 meters and with high temperatures [40]. The rapid spreading of the pest is enhanced by the pest habit of displacing the native species thus becoming the most injurious stem borer in Africa [31]. For example, in coastal Kenya, *C.partellus* displaced the indigenous stem borer *Chilo orichalcociliellus* (Lepidoptera: Crambidae). Similarly, in the eastern highveld region of South Africa, *C.partellus* partially displaced *B.fusca* over a period of seven years. Within two years, it became the predominant borer; constituting 90% of the total stem borer populations. One of the possible reasons for the replacement of the indigenous species is that hibernating larval populations of *C.partellus* terminate diapause and emerge a month earlier than *B.fusca* [22]. In addition, the life cycle of *C.partellus* is three weeks shorter than that of *B.fusca,* which gives it a further competitive advantage because of its higher population growth rate [31]. In Northeastern Ethiopia, *C.partellus* makes up 7 to 100% of the population of stem borer species and cause damage of 1 to 100% in the same zone at the elevation region from 1492 to 2084 [31]. In Zimbabwe, the pest is reported with high infestation levels on dry-season irrigated maize at an altitude below 600 meters [38]. Evidence also shows that the species is colonizing high elevation areas in eastern and southern Africa [31]. [26] reported that *C. partellus,* is one of the most important and destructive pests of maize and sorghum at altitude below 1500 m above sea level in India. In Mozambique, *C.partellus* is the most abundant stem borer species at lower altitudes (0-200m) and in warm zones with 100% infestation levels [11]. *C. partellus* (Swinhoe) and *B. fusca* are important stemborer species in Kenya in the warmer and lower areas and in the cooler and higher altitudes respectively [46]. In Ethiopia, *C.partellus* was recorded in elevation between 1030 to 1900 m [24]. In Eritrea, *C.partellus* and *B.fusca* were important in highlands between 1450-2350 m and low lands less than 1400 m, respectively [1].

2.2. Busseola Fusca (Fuller)

B.fusca is native to Africa and often considered the most important field pest of maize in Sub-saharan Africa [3-17-6-34]. It is a pest that is always present where cereal crops (maize and sorghum) are cultivated in Africa. It was first recognized as a pest of maize in South Africa, where much of the early work on its biology and control was done. *B. fusca* (Fuller) occurs throughout mainland Africa south of the Sahara and has been recorded from West Africa (Benin, Burkina Faso, Cameroon, Cote d'Ivoire, Ghana, Guinea, Mali, Nigeria, and Sierra Leone), from Eastern Africa (Ethiopia, Kenya, Somalia, Tanzania, and Uganda) and from Southern Africa (Angola, Botswana, Lesotho, Malawi, Mozambique, Rwanda, South Africa, Swaziland, DR Congo, Zambia and Zimbabwe) [27]. *B.fusca* (Lepidoptera: Noctuidae) and *C.partellus* (Lepidoptera: Pyralidae) are the dominant species in East Africa [49]. In Central Africa, it is the predominant pest across all altitudes. The extension of maize cultivation in Africa may have enabled the pest to follow the crop and become established in most African countries. The distributions of *B. fusca* and *C. parellus* are affected by rainfall, temperature and elevations in Sub-saharan countries [22]. In Burundi, *B.fusca* was the only species detected in the high-altitude (2100 m) location of Gisozi with 80% infestation in maize and sorghum. In Cameroon, it is a predominant borer species accounting for more than 90% of all species. In the Democratic Republic of Congo, *B.fusca* appears to be the most predominant stemborer species. In Zimbabwe, *B.fusca* is dominant in areas with an altitude above 900 meters [12], highveld (>1200m) and middleveld (600m -1200m) [17]. In addition, its population level is influenced by intensity of cultivation of crops such as maize and sorghum [32]. *B.fusca* can also survive in maize stubble or on wild grass hosts. In Ethiopia, it is ranked the highest among the pests that damage maize crop. Yield losses depend on the stage of the plant at infestation and the damage can be as high as 20%. In the Guinea savanna agro-ecological zone of Nigeria, *B.fusca* is the most predominant borer species in early and late planting [47]. In Ghana *B.fusca* is considered the most important pest of maize. In Kenya, the distribution of *B.fusca*, *C.partellus*, *S.calamistis* and *C.orichalcociliellus* are different but often overlap in space and time [49]. In the lowland tropics of West, East and Southern Africa, *B.fusca* is generally of low importance but in Central Africa countries like Cameroon it is the predominant species across all eco-zones and altitudes [43]. In Southern Benin, *B.fusca* was found only in Yoto district causing serious damage on maize [56].*B fusca* generations occur differently from one region to another. In Ibadan in southern Nigeria, four larval generations have been observed on maize. In Ethiopia, three generations have been recorded with peaks in May-June, July-September and October. In South Africa, the number of generations on maize increases from two in the East to three in the West with peak moth emergences in October-December, January and March. Generations tend to overlap towards the west and seasonal variations in flight patterns are less distinct. In Zimbabwe two distinct generations emerge in November and January-February and a third generation may develop when conditions are favorable. At all locations, most larvae of the final generation enter diapause and survive until the following growing season inside dry maize stems and stubble [9].

3. Host Plants

Cereal stemborers are polyphagous and have several gramineous and other non cultivated wild host plants. The original host plants of all cereal stemborers were wild grasses [11]. However, sorghum and maize are the most important host plants for stemborers. They have different preferences in terms of host plants. For instance, *C.partellus* prefers sorghum to maize [40]. *C.partellus* is a generalist herbivore that feeds on several species of cultivated and wild plants belonging to the graminacea [48 - 37]. *B.fusca* prefers maize to sorghum.*C.partellus* has been observed damaging Pearl millet, rice, wheat and sugarcane in the field. According to [40] stemborer wild host plants are found in the Graminae, Cyperaceae and Typhaceae families. In Kenya, some of the Gramineous species which are hosts to *C.partellus*, *B.fusca* and *S.calamistis* are *Hyparrenia*, *Pannicum*, *Pennisetum*,*Setaria*, *Sorghum*,*Sporobolus* spp, and *Andropogon* spp. In addition, *B.fusc*a, *C.partellus* and *S.calamistis* have been recorded on 24 wild plant species in the family of graminae. In Zimbabwe, only maize, sorghum and sugarcane can be mentioned with certainty as hosts [16]. Finger millet (*Eleusine cocacana*) and bulrush millet (*Pennisetum glaucum*) are widely grown in Zimbabwe but their importance as stem borer host plants has not been investigated [16]. In the wild host group, Napier grass, (*Pennisetum purpureum* Schum) was reported to be an important *B.fusca* host in Zimbabwe. This host is more attractive to gravid females than maize plants [43].

4. General Stem Borer Damage and Larval Behavior

Most stem borer species produce similar symptoms on maize and sorghum plants. Among cereals, maize is damaged more by stem borers because it has more of amino acids, sugars, than the other gramineous hosts [53]. In addition, maize emits volatile compounds identified coupled gas chromatography- electro-antennographic detector (GC-EAD analysis): Copaene, (Z)-3-hexenol, (E)-2-hexenol, 3-hexenyl acetate, (Z)-3- hexenyl acetate, linalool, 4.8-dimethyl, (E) –b –farnesene, (E)-nerolidol, (3E,7E)-4,8,12- trimethyl-1,3,7,11-tridecatetraene. Of these volatile compounds, those emitted by Z. *mays* L. are more attractive to *B.fusca* than they are to *C.partellu*[45].Generally, soon after hatching, stem borer larvae crawl over the plant, congregate in the funnel and feed on the rolled leaves a few days before penetrating into the stalk and stem [40]. As the leaves grow away from the funnel, a characteristic pattern of holes and "window panes" can be seen, leaving transparent upper cuticle referred to as window panning [9]. Window panes refer to early larval feeding in which the larvae do not completely chew through the leaf but leave a thin layer of transparent leaf epidermis. Larvae can also feed on basal meristems of young maize plants resulting in the formation of dead heart. Dead heart is caused by the borers boring into the stalk at the soil level and tunneling upward. Dead hearts cause death of cereals such as maize, while sorghum, millet and rice compensate by tillering. Older larvae make holes and tunnels in stems where they feed for 3 to 5 weeks causing extensive tunnels. Larval tunneling within the stalk may also predispose plants and ears to infection by fungal pathogens, further compromising the long-term storability, and quality of food products [31]. There is an evidence of variation in the lengths of stem tunneling associated with the different stem borer species. *B.fusca* larvae produce the largest stem tunneling, followed by *C.partellus*. Mostly, the holes are prepared for pupation. The feeding habit reduces the flow of water and nutrients throughout the plant, and can reduce grain weight, kernel number, therefore reducing yields [30]. The extensive tunneling of stem borers inside the stems weakens the plants causing breakage and lodging [55]. On the effect of lodging on the plants, [28] reported that lodged plants are likely to yield lower and make harvesting more difficult. This agrees with [51] who reported that yield losses as high as 40% could result from lodging. Damage to the stem can lead to the infection by Fusarium stalk rot [40]. Other plant parts such as tassels and ears are prone to stem borer damage. Extensive damage can result in complete death of the plant. After killing the plant, larvae usually migrate to new plants and enter by boring into the stem near the base. Plants damaged by stem borers are often stunted and may die. Infested plants if they survive may or may not produce harvestable ears. If they do, they are usually smaller than normal plants making them less marketable especially if they are sold as green mealies. In addition, those plants that do not produce ears compete with plants for water, nutrients and sunlight [5]. The magnitude of the damage is influenced by soil fertility [13], farming systems [54-14] and maize cultivars. In the Southern lowveld of Zimbabwe, *C.partellus* exhibits a facultative diapause and causes extensive damage to both rain fed and off-season irrigated crops [16].

5. Yield Losses Due to Maize Stem Borers in Africa

Yield loss due to stem borers in Africa vary from 0-100% among ecological zones, regions and seasons. In Sub Saharan Africa, they can cause 20-40% losses during cultivation and 30-90% losses postharvest and during storage [45]. The severity and nature of stem borer damage depends upon the borer species, the plant growth stage, the number of larvae feeding on the plant and the plant's reaction to the borer feeding. Feeding by borer larvae on maize plants usually results in crop losses as a consequence of death of the growing point (dead heart), early leaf senescence, reduced translocation, lodging and direct damage to the ears. In Zimbabwe, trial-generated data on maize yield losses due to the stem borers are scanty. However, estimated yield losses of 10-43% are expected to occur at the smallholder level where suppression of the pest by chemicals is generally not practiced. Yield losses of 12% for every 10% plants infested were reported in Tanzania and Kenya [32]. In Côte d'Ivoire, a statistical model of crop losses, based on six experiments on maize indicated that plant destruction was mainly caused by *B. fusca* and that crop losses could be accurately estimated on the basis of samples taken 40 and 80 days after crop emergence. Crop losses decrease when stand density was reduced and increased when the crop was suffering from water stress [33-9]. Yield losses depend on the age of the plant at infestation. In Ghana, yield loss as high as 40% has been attributed to *B.fusca* infestations. In Democratic Republic of Congo (DRC) *B.fusca* occasionally caused yield losses of 8-9% in early planted maize, and 22-25% in late planted maize [42]. In Kenya, *B.fusca* accounted for 82% of all maize losses [20]. *C.partellus* is the most damaging pest in eastern and southern Africa [31] and causes significant grain yield losses. Its control has been a challenge among smallholder farmers [41]. *B.fusca* can feed on maize kernels at maturity [40]. *B.fusca* larva produces higher effect on grain weight reduction as compared to *C.partellus.*In Ethiopia, *B.fusca* and *C.partellus* are considered to be the most damaging insect pests, with reported yield losses of 0 to 100, 39 to 100, 10 to 19 and 2 to 27% from South, North, east and Western Ethiopia, respectively [36]. In South Africa, annual yield loss caused by stem borers to maize is 10% although between 25-75% loss has been recorded. In Mozambique, [11] reported yield losses of over 50% due to *C.partellus* in the smallholder farming sector. In Maputo and Gaza provinces of Mozambique and the Limpopo valley, estimated yield losses of 100% was reported to be caused by *C.partellus*. The larvae of the 3rd generation were reported to infest 87% of cobs of maize planted late and to severely damage 70% of their grain. Yields in East Africa were reduced by 15-45% by *C.partellus* alone. In South Africa, yield losses in maize and sorghum have exceeded 50% [18]. In Kenya, [21] found that all stem borer species caused average annual losses of 13.5% valued at US$80 million. Losses to *C.partellus* were estimated at US$ 23 million/year; the majority of other stem borer losses were attributed to *B.fusca*. This analysis was based on maize prices of $193/ton. In Israel the rate of damaged ears of maize by *C.partellus* ranged from 30% to 70% [4]. In Zimbabwe, stem bores are the most important insect pests of maize and are capable of completely destroying the crop. Yield losses of 10% to 40% have been estimated. Borer infestations range from 30 to 70% in fields of resource-poor farmers, and are less than 30% in commercial farms, where insecticides are used for control. In Burundi, *B.fusca* caused yield loss of 30-50% in regions between 1500 and 2100 m.In Kenya, yield losses of up to 18% due to *C.partellus* and *Chilo orichalcociliellus* have been reported [26]. Maximum grain yield reduction and stalk damage in maize was reported due to *C.partellus* on 20-day-old crop, while there was insignificant larval effect on yields for 60-day-old crop. The economic injury levels (EIL) of *C.partelus* in maize are 3.2 and 3.9 larvae per plant in maize 20 and 40 days after plant emergence, respectively. Generally, the amounts of yield loss vary greatly depending upon the country, season, maize variety, fertilization, severity of damage, stem tunneling and generation of stem borers involved. The first and second generations causes more yield loss than the third generation[31-20].

6. Pest management

6.1. Chemical Control

Cultural methods and practices that can be used to control stem borers include appropriate crop residue disposal, planting date manipulation, host resistance, destruction of volunteer and alternative host plants, tillage practices, crop rotation and intercropping [16]. These control measures do not guarantee 100% control, but help to reduce infestation and enable sustainable maize production [30]. Cultural control is useful because it combines effectiveness with minimal extra labor and cost [40]. Appropriate disposal of crop residues after harvest can reduce carry-over populations of diapause larvae of stem borersand so limit initial establishment of the following season’s crop. Later sowing of maize is less affected by stem borer larvae than earlier sowings as it disrupts their seasonal cycle [30]. It is thought that at the start of the rainy season, borer populations arising from diapausing-generation larvae will still be building up, so fewer moths will oviposit on early planted crops [17]. In Ethiopia, the infestation of late-sown maize, attacked by the second generation of *B.fusca* was higher (22-100) than early-sown maize attacked by the first generation (0-22%) [23]. Host resistance to insect is the genetic property that enables a plant to avoid, minimize, tolerate or recover from injury caused by the pests. These plants have genetic traits which manifest as antibiosis, in which the biology of the pest is adversely affected after feeding on the plant. Furthermore, they can have genetic traits which manifest as antixenosis (non preference) where the plant is not desirable as a host and the pest seeks alternative hosts. They can also be tolerant and able to withstand or recover from the pest damage [38]. Destruction of volunteer and alternative host plants reduce overwintering and hibernation of stem borer species. Stubble is probably the main source of initial stem borers infestation in subsequent seasons [32]. Deep ploughing is effective as it brings the larvae and pupae to the soil surface [40]. The larvae will be then exposed to the heat from the sun and predators like cattle egret (*Bubulcus ibis*). Deep ploughing also controls stem borers because by burying, pupae and stem borer moths do not emerge from great depths. However, zero tillage provides insect pests with shelter from plant materials. This may lead to an increase in the number of pests and must be avoided if stem borer numbers are to be reduced[40].

6.2. Biological Control

Natural enemies play an important role in the control of lepidopterous borers in Africa. Biological control is the use of parasitoids, predators, nematodes and/or pathogens to maintain density of a species at a lower level than would occur in their absence. The main attraction of this control is that it lowers the need for using chemicals and there is limited environmental pollution, which may affect non-targeted flora and fauna [40]. It usually offers a lasting solution of stemborer control from one introduction hence beneficial to both smallholder and commercial farmers. Some parasitoids attack eggs, some attack larvae, while some attack pupae. *Trichogramma* spp.(Hymenoptera: Trichogrammatidae) and *Platytelenomous busseola* (Hymenoptera) are egg parasitoids, that contribute to natural mortality of stem borers. Hymenopteran parasitoids like *Cotesia* spp. have highly specialized ovipositors for stinging and depositing eggs in the host. The sting causes permanent paralysis in the host body [40]. *Trichogramma* spp. parasitize eggs of stem borers while *Cotesia* spp. parasitize larvae of stem borer species [11]. Egg parasitism offers good control in that it stops the emergence of the damaging larval stage [40]. *Dentichasmiasis busseolae* (Heinrich) (Hymenoptera: Inchneumonidae), *Pediobus furvus* (Gahan) (Hymenoptera: Eulophidae) and *Lepidoscelio* spp. *Xanthopimpla stemmator* (Thunberg) (Hymenoptera: Ichneumonidae) are parasitoids of stem borers. In South Africa, *Procerochasmiasis nigromaculatus* Cameron (Hymenoptera: Ichneumonidae) was recorded with up to 100% pupal parasitism on *B.fusca*. In addition, in South Africa, *Dentichasmiasis busseolae* caused up to 100% pupal parasitism of *C.partellus*. Furthermore, in South Africa the parasitoid *Cotesia sesamiae* (Cameron) (Hymenoptera: Braconidae) accounted for up to 90% of parasitized *B.fusca* larvae, but have not yet been able to maintain populations below economic threshold levels [32]. Parasitoids of hosts which feed in exposed situations usually pupate in protective silken cocoons produced by the larvae themselves. Some parasitoids can pupate within the eaten out body of the host [40]. In Ghana, exotic species of *Trichogramma* showed high fecundity and helped to control stem borers, including *B.fusca*. In Southern Benin, *Telenomus busseola* (Ghana) (Hymenoptera: Sclionidae) and *Telenomus isis* (Polaszek)(Hymenoptera: Sclionidae) are the most important natural control factors of stembores, including *B.fusca* on maize [55]. In Ethiopia the Braconid, *Dolichogenidea fuscivora* was found to be the major larval parasitoids of *B.fusca* with parasitism as high as 71% in the dry season and 18% in the wet season. *Cotesia sesamiae* (Cameron) (Hymenoptera: Braconidae) is the most important larval parasitoid of *B. fusca* with 20% to 25% parasitization in Ethiopia [18]. It is also a gregarious larval endosparasitoid of *S.calamistis*. *Pediobius furvus* Gahan is a gregarious primary pupal parasitoid of *B.fusca* in maize and sorghum in Ethiopia. According to [18], *Stenobracon rufus* is a solitary pupal parasitoid of *B.fusca* attacking maize and sorghum in Ethiopia with 14% parasitization. In Zimbabwe, many natural enemies associated with maize stem borers have been recorded on the highveld region and outside the highveld [17]. These include parasitoids such as the *Bracon sesamiae* Cameron (Hymenoptera: Braconidae), which attacks larvae of *B.fusca*, *Chelonus curvimaculatus* Cameron (Hymenoptera: Braconidae), which attacks larvae of *B.fusca* and *C.partellus*, *Cotesia sesamiae* Cameron (Hymoneoptera: Braconidae), which attacks larvae of *B.fusca*, *C.partellus* and *S.calamistis*, *Dolichogenidea palaszeki* walker (Hymenopetera: Braconidae), which attacks the larvae of *B.fusca*. *Dentichasmias busseolae* Heinrich (Hymenoptera: Ichneumonidae), which attacks pupae of *C.partellus* and *Procerochasmias nigromaculatus* (Cameron) (Hymenoptera: Ichneumonidae), attacks pupae of *B.fusca*. *Pediobius furvus* Gahan (Hymenoptera: Eulophidae), also attacks the larvae of *C.partellus*. *Sturmiopsis parasitica* (Curran) (Diptera: Tachinidae), attacks larvae and pupae of *B.fusca* [16]. [16], also noted that pupal parasitoids such as *Procerochasmias nigromaculatus* (Cameron) and *Dentichasmias busseola* Heinrich were frequently recorded from the field. However, owing to the low numbers of pupae collected, the actual field parasitism rates could not be determined. Generally, the levels of stemborers parasitism by indigenous natural enemies are not satisfactory. *Cotesia flavipes* (Hymenoptera: Braconidae) was imported and released due to low background of low parasitism by native parasitoid species in Zimbabwe between 1999 - 2002. Prospects for its final establishment appear to be good mainly for two reasons: Firstly, the predominance of *C.partellus* which is it preferred host eliminates the possibility of non-establishment due to host unsuitability. The climatic conditions prevailing in Zimbabwe lowveld favor the continuous cultivation of maize throughout the year with the result that actively feeding *C.partellus* larval stages persist throughout the year [17].

Cotesia flavipes was introduced into Africa from the Indian Sub-continent for biological control of stem borers. It is known to have established in Kenya, Madagascar, and Mauritius. The parasitoid's impact has recently been evaluated in Kenya after establishment, and a reduction of 37% of the total stem borer populations and a reduction of 53% *C.partellus* population has been observed in some areas [59]. *C. flavipes* was found to have successfully established and satisfactory levels of *C.partellus* control in Mozambique [12-11], in Kenya [52], in Tanzania, in Uganda[35] and in Zambia. *C.flavipes* is also a gregarious larval endoparasitoid of *S.calamistis*. Parasitoids locate borers by laying eggs into them while feeding inside the plant stems. When they will hatch, the larvae of the parasitic wasp will be feeding internally in the pest and kill it and then exit to spin cocoons [17]*Hexametric* sp. (Mermithidae) is an entomoparasitic nematode that controls stembores [15].

Predators are valuable components of Integrated Pest Management (IPM). Ants (Hymenoptera: Formicidae) are the most important predators of stem borers in maize fields [7]. They attack all stages of stem borers, and are among the few predators preying on stem borer larvae and pupae. According to [40], *Componotus* spp. (Formicidae) and *Pheidole* spp. (Formicidae) appear to be the most important and common species in Zimbabwe. Ants of the genus *Lepisiota* were reported preying on eggs and larvae of stem borers [7]. In Ethiopia, Earwigs (Dermaptera) and ants were commonly seen preying on *B.fusca*[58]. Entomopathogenic viruses, bacteria and fungi can be used as pathogens to control insect pests. *Bacillus thuringiensis* (Bt) lowered stem borer larvae in Kenya with a consequent increase in the yield. *Beauveria bassiana* is known to control *C.partellus* by infecting insect hosts through the skin penetration. This makes them readily able to kill piercing and sucking pests which may not be killed by stomach poisons. High humidity is needed in this case for *Beauveria bassiana* germination [40].

6.3. Chemical Control

Chemical insecticides are used in some Sub-Saharan countries for the control of lepidopterous borers. These chemical insecticides fall under different chemical groups namely, Methyl and dimethyl carbamates of heterocyclic compounds, organochlorines, organophosphates and carbamates such as carbofuran. However, the majority of African farmers cannot afford to buy insecticides, which are seldom available on time. These farmers also have limited knowledge on the safe use of the insecticides. In addition, insecticides have negative impact on the environment as they are a health hazard to humans and may not be compatible with other means of control such as biological control. In Zimbabwe, stemborer control using chemicals dates back to the beginning of the last century. Some of the earliest chemicals recommended on maize included carbolic and arsenic cattle dips [2]. Currently, several insecticides, formulated as either granules or spray applications, are registered for stemborer control in Zimbabwe [16]. The most common ones include carbaryl, endosulfan, dipterex (trichlorforn), synthetic pyrethroids and carbofuran. These chemicals have been screened in both maize and sorghum in various agroecological regions of Zimbabwe and found to provide effective control [16]. Insecticide such as Carbofuran at 1.0-2.5kg/ha gave good stem borer control up to seven weeks after emergence in South Africa and in Nigeria. Pyrethroids have been found to be effective for the control of *B.fusca* in Burundi. In Cote d'Ivoire, deltamethrin as an emulsifiable concentrate at 15 g active ingredient/ha and carbofuran as granules at 200 g active ingredient/ha gave economical control of *S.calamistis* and other stem borers in maize. However, none of the insecticides (i.e edosulfan, chlorpyrifos-ethyl (chlorpyrifos), phoxin, carbofuran, deltamethrin, cypermethrin and *Bacillus thuringiensis*) controlled borers found in the ear. A single application of endosulfan against *C.partellus* was beneficial when applied shortly before tasselling in maize and before panicle emergence in grain sorghum in South Africa. In Mozambique, it was shown that when insecticides are applied against *C.partellus* in maize, yield can increase two-to four fold. The recommendation being to apply diazinon twice into the whorl, when the plants are 3 and 5 weeks old. Placement of granular dusts of endosulfan, carbaryl, malathion, or fenvalerate and bulldock in maize leaf whorls are effective in controlling stem borers. For example, Bulldock (beta-cyfluthrin, Bayer Ltd) and Dipterex (trichlorfos, Bayer Ltd) were the most frequently used granular insecticides in Kenya and gave good control of stem borers [8]. However, caution must be given to soil systemic insecticides as they are not suitable if the maize crop is intended for consumption as green mealies. Green mealies are harvested much earlier than grain maize, and residues of the chemical may still be higher than desired within the plant. In addition, chemical control may also result in low population levels of parasitoids and possibly other natural enemies [31]. The time of application of any kind of spray is crucial because stem borers are difficult to control with insecticides [57]. The reason presumably being that, existing spray-based practices have been found ineffective against internal feeders and are costly and hazardous [29-19]. Spraying should be done before the moths lay their eggs or when larvae are at their most vulnerable stage (feeding at the base of the leaves). Insecticides should be sprayed before most larvae reach tunnel into stalk and cannot be controlled with insecticides [30].

7. Conclusion

Lepidopterous stem borers *B.fusca* and *C.partellus* result in economic damage to maize in many African countries, with smallholder farmers suffering more severe losses than large-scale ones. As such, the ideal stem borer control strategy that would suit the economy of maize cultivation at the smallholder sector level is an integrated one to reduce the losses that the pest is causing on maize yield.The combination of cultural, chemical and biological controls will play a pivotal role in such a strategy and keep borer populations at lower levels.

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