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Research Article

Preliminary control strategies of *Spodoptera frugiperda* (Smith), invasive Lepidoptera of maize in tropical region

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Abstract: The following study was conducted in South Kivu Province and its concerning Uvira-lawland and Kabare-highland. An experimental of tree crop systems (NPK-Manure, Natural Fallow and Agrofostry + NPK-Manure) against *Spodoptera frugiperda* (FAW) was done at Kabare-highland. The overall objective of this work is to contribute on determination of *Spodoptera frugiperda* incidence and comparison of this impact in two lands (high and low), and which cultural practices integrates agro-forestry and micro doses of fertilizers can control the fall armyworm, and the cost of labor for the collection of FAW during the two growing seasons A and B. The methods of prospecting of maize plants and one way ANOVA were done like statistical analysis. The study results showed that the percentage of infested plants at Uvira-lowland was highest during period of maize cultivation, the physics and the populating climatic characteristics have an impact on the land. FAW were infested all crop systems Agroforestry+ NPK-Manure, NPK-Manure and Naturel fallow. The incidence of fall armyworm (FAW) on maize plants was no important on Agroforestry+ NPK-Manure crop system, but highly on two others crop systems, NPK-Manure and Naturel fallow. The FAW were abundant on NPK-Manure and Naturel fallow crop systems too. Agroforestry + NPK-Manure is the benefic crop system therefore using few men-day (5 to 8) and cost (5 to 8 $ USA). This crop system constituted the barrier of attack therefore the few number of caterpillars FAW (60 to 470) could restore soil fertility and supply fodder for livestock. Given the above, it is strongly recommended that all neighbors countries to form a group of management strategy that should include strong farmer for the identification and the alert system and used the polyculture (Agroforestry crop system) to faith against the FAW.
Keywords: *Agroforestry, Manure, Natural fallow, caterpillars, crop system, lowland, highland and fall armyworm*.

BACKGROUND

Climate change, through rising average temperatures, increased variability of rainfall (frequency; intensity),increased atmospheric greenhouse gas concentrations, increased frequency and severity of storms and rising sea level, will affect the invading species, its invasive potential and the invasibility of the host ecosystem, be it native or derived. The greatest impacts of climate change on invasive species may arise from changes in the frequency and intensity of extreme climatic events that disturb ecosystems, making them vulnerable to invasions, thus providing exceptional opportunities for dispersal and growth of invasive species (Masters and Norgrove, 2010).

The fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith 1797), belongs to the order Lepidoptera and the Noctuidae family. Due to its polyphagous behavior (Clark *et al.*, 2007; Murúa *et al.*, 2009), high voracity, ability to form large populations, and high dispersion rates, this species is considered a cosmopolitan pest, one of the most destructive in America. (Murúa *et al.*, 2003; Clark *et al.*, 2007). The fall armyworm feeds on more than 60 species of plants, especially maize, rice, sorghum, grass, cotton, peanuts, alfalfa, oats, sugar, onions, beans, potatoes, tomatoes,

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wheat, soybean, beaver oil plant, sesame, melon and sunflower among others (Murua *et al.*, 2003; Zenner *et al.*, 2007) but it considered the most important pest in maize (*Zea mays* L.) in the Americas (Clark *et al.*, 2007). Williams *et al.*, (1999) show that the larvae consume the plant whorl affecting its growth, and complete defoliation could arise when epizooties occur.

The FAW, *Spodoptera frugiperda* is a native prime noctuid pest of maize on the American continents (American tropical and subtropical area) where it has remained confined despite occasional interceptions by European quarantine services in recent years (Goergen *et al.*, 2016; IITA , 2016).

Several studies have been done in the world: Carvalho in 1970; Carvalho *et al.*, (1984); Carvalho (1984); Ghidiu and Drake (1989); Harrison (1984 a); Leuck (1972); Leuck and Hammons (1974); Leuck *et al.*, (1974) ; Marenco *et al.*, (1992) ; Wiseman *et al.*, (1966, 1973 a and b) worked on fall armyworm. (Murúa *et al.*, 2003) were conducting research on natural enemies, resistance testing with new insecticides and molecules in the development of biotechnological research. Villa & Catalán (2004) were determining the various larval stages. This is a basic issue when constructing growth prediction models. Cruz conducted several studies on fall army as Cruz (1980), Cruz and Turpin (1982 and 1983), Cruz *et al.*, (1996) and Cruz *et al.*, (1999) were conducted to assess the damage caused by the fall of the *Spodoptera frugiperda* larvae in Al-tolerant and Al-susceptible maize cultivars at different levels of Al saturation (low, medium and high) in an acid soil. Murúa *et al.*, (2006) were condacted research on fall armyworm dynamics and parasitoids in argentina. Those authors: Molina-Ochoa *et al.*, (2001); Morillo and Notz (2001); Murúa and Virla (2004); De Melo *et al.*, (2006) and Zenner de Polanía *et al.*, (2009) show that in their studies, approximately 3,000 tons of active ingredient in the fall (*Spodoptera frugiperda* Smith) (Blanco *et al.*, 2010), the most important maize pest in the American continent. Binning *et al.*, (2014) conducted the research on susceptibility and aversion of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) to Cry1F Bt Maize and considerations for insect resistance management and Cuartas *et al.*, (2015) worked on the complete sequence of the first *Spodoptera frugiperda* Beta baculovirus genome: A natural multiple recombinant virus. (Robert *et al.*, 2016) were conducting research on parasitoids attacking fall armyworm (Lepidoptera: Noctuidae) in sweet corn habitats.

According IITA (2016), Goergen *et al.*, (2016), and Matthew Cock *et al.*, (2017), for the first time in Africa, this invasive pest *Spodoptera frugiperda* was mentioned in Nigeria, Togo, Benin and Sao Tome. Again, it was declared in Ghana (CABI 2017) and Zimbabwe (FAO ,2017a) and et preliminaries signalling in au Malawi, Mozambic, Namibia, South Africa and Zambia (BBC , 2017), below figure 1, the map of distribution of *Spodoptera frugiperda* in the world (CABI , 2016).

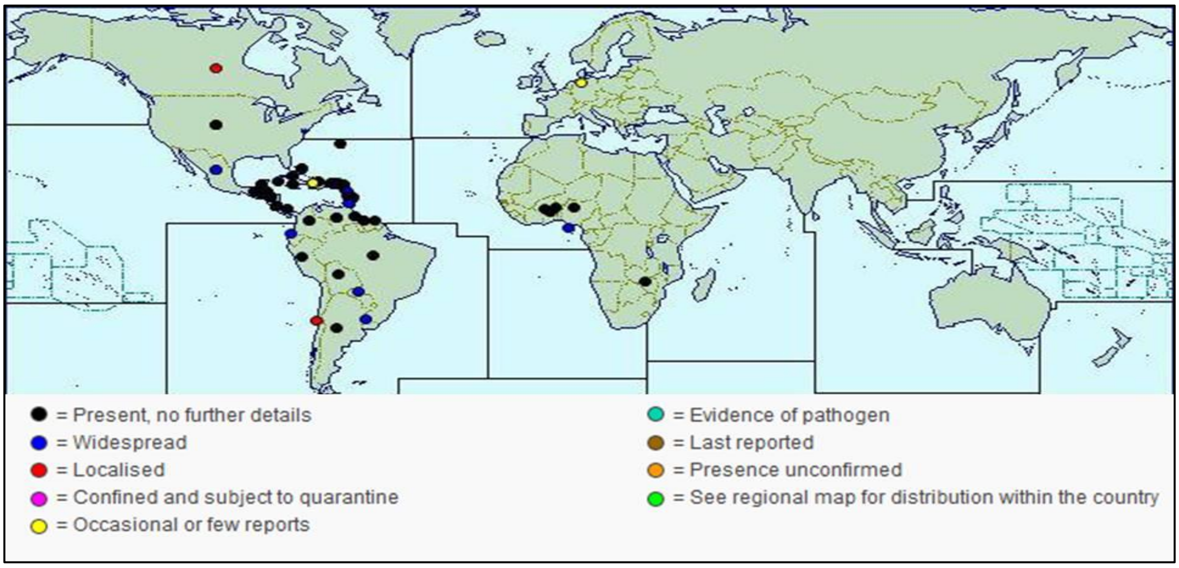

Fig.1. Distribution of *Spodoptera frugiperda* in the world (CABI, 2016)

In the recent past, maize has faced serious production and post-harvest challenges. While *Spodoptera frugiperda* has been the most serious field pest in highland and devastating in lowland DRC. Such eating result to total failure of maize. The note the way the caterpillar cuts the maize; and the worm frass (feces) deposited on the leaves haphazardly and in large amounts. This pest has been introduced into the country and and does not have attention. Fall armyworm late instar caterpillar feeding on an off season and season maize at DRC. No studies have been done in South-Kivu province and, only a few reports (FEWS NET RDC, 2017; Radio Okapi, 2017; FAO, 2017 b) have been published on *Spodoptera frugiperda* of the

Democratic Republic of the Congo (DRC), in which showing that since October 2016 in Democratic Republic of Congo especially in South-Ubangi, High-Katanga provinces and Batéké upland in town province of Kinshasa, maize field was attacked.

According to Analyses Unit of Indicators of Development in DRC (CAID), 50 territories of 147 territories which count country, that to say 30 % of national territory were presently affected. The damage recorded appeared enormous seeing that the attack destroyed the last output of agricultural period of September and December 2016. These attacks occasioned a serious absence of corn and high price which threefold in few weeks with reference to early loss in affected areas (FAO, 2017 b).

In the tropical lowlands, there may be a lack of species that can adapt to the higher temperatures to replace those more temperature sensitive species whose ranges are forced to higher altitudes. Possible consequences are significant attrition of lowland tropical biodiversity and/or successful invasion by species able to adapt to hotter conditions. Replacement of natives by invasive species will be one of the major impacts of climate change, but there will be others such as changing relationships between predators, pathogens and prey (with either native or introduced species), changing fire regimes, and other climate harm to species already threatened by invasive species. Climate change threatens economic development in many countries, particularly in tropical countries, where climatic variability is already a significant challenge to poverty alleviation. It is essential that key indicators of the onset of climate change impacts are developed and monitored, with appropriate thresholds set to establish not only when action should take place but what type of strategy should be adopted (Masters and Norgrove, 2010).

Indeed the cereal-legume associations could contribute to the development of agriculture that combines productivity and high environmental value. They appear, in conventional farming, as an efficient way to produce as much (yield, protein content) as the average of the pure cultures with much less nitrogen inputs and thus induced energy consumption (Naudin *et al.*, 2010; Bedoussac *et al.*,2010; Pelzer *et al.*,2012). However, association is a way of bringing the simultaneous culture of two or more species into the same space and for a significant duration of their cycle (Willey, 1979).

Pelzer *et al.*, (2012) show that they are more competitive than vegetables because of their deeper root systems and faster growth. In the case of companion cereal-legume combinations, the leguminous plant is a crop that can remain in place until the harvest of the cereal, and this until the establishment of the next crop, and which provides only agro-ecological functions throughout the cycle of the cereal and in the longer term: reduction of weed infestations, regulation of bio-aggressors, trapping of excess nitrate, contribution to soil organic nitrogen stock, maintenance and improvement of soil structure, increase of biodiversity on the agricultural parcel. Those authors (Naudin *et al.*, 2010; Corre-Hellou *et al.*, 2006; Hiltbrunner *et al.*, 2007) show that the functioning and performance of cereal-legume associations depend strongly on the nitrogen availability of the plant on region. Nitrogen fertilization (dose and date) can be considered as an important step in the final mixture. However, the other elements of the technical itinerary may be such as density or variety choice but, that itinerary have been less explored. Silvain *et al.*, (1981) noted that, on the agronomic plan, the meadow fertilizer correctly supported well Noctuidae attack, as the former or grass suffers already on currency. At the first case, we can assist on the fast resumption of vegetation after pest attack, but on the case of the meadow badly fertilizer, it assist to disappearing of all grass. The former can resist at the level of the windrow where an important organic deposits exist.

Many technical questions remain on the design of technical itineraries for these cereal-legume seed and forage combinations and companion legume cereal combinations aimed at satisfying different outlets with high levels of production and quality of harvested products and minimizing inputs and reasoning place of these associations in the succession of cultures. In addition to those listed above, another unknown scientist is the application of this technique to the regulation of bio-aggressors. The maize cultivation is currently subject in all African countries to the attack of *Spodoptera frugiperda* and the latter is resistant to all forms of insecticides. Given the importance of maize in the African continent, the mobilization of the population to find solutions to this new invasion would be an asset to produce better. Thus, associations could be of interest for controlling certain pests, but the conclusions could not be generalized because of the mechanisms specific to each pest. Hence the research of invasive lepidoptera (Noctuidae), *Spodoptera frugiperda* (Smith) and preliminary control strategies on maize in tropical region.

The overall objective of this work is to contribute on determination of *Spodoptera frugiperda* incidence and comparison of this impact in two lands (high and low), and which cultural practices integrates agro-forestry and micro doses of fertilizers can control the armyworm, *Spodoptera frugiperda*, and the cost of labor for the collection of *Spodoptera frugiperda* during the two growing seasons A and B.

MATERIALS AND METHODS

Study Area: Location Area

The Democratic Republic of Congo is in tropical region and the South Kivu Province is located on the eastern part of the Democratic Republic of Congo. South Kivu relief includes mountains, the Mitumba ranges, whose most important mountain is the summit of Kahuzi-Biega, 3340 m of attitude (DSRP, 2005). The climate of South Kivu has nine months of rain and three months of dry season, it is a humid tropical climate (Ngongo and Lunze, 2000). South Kivu has an average annual temperature of between 16 and 20 ° C. The rainfall regime is bimodal; it allows thus two farming seasons, the first season (A) spreading from mid-November to mid-November and the second (B) from mid-March to mid-June, followed by a short so-called C season characterized by cultivation in valleys after marsh drainage during the dry season (Pypers *et al.*, 2010). The average annual rainfall is 1,572 mm (Ngongo and Lunze, 2000). The study area was illustrated with the figure 2, below.

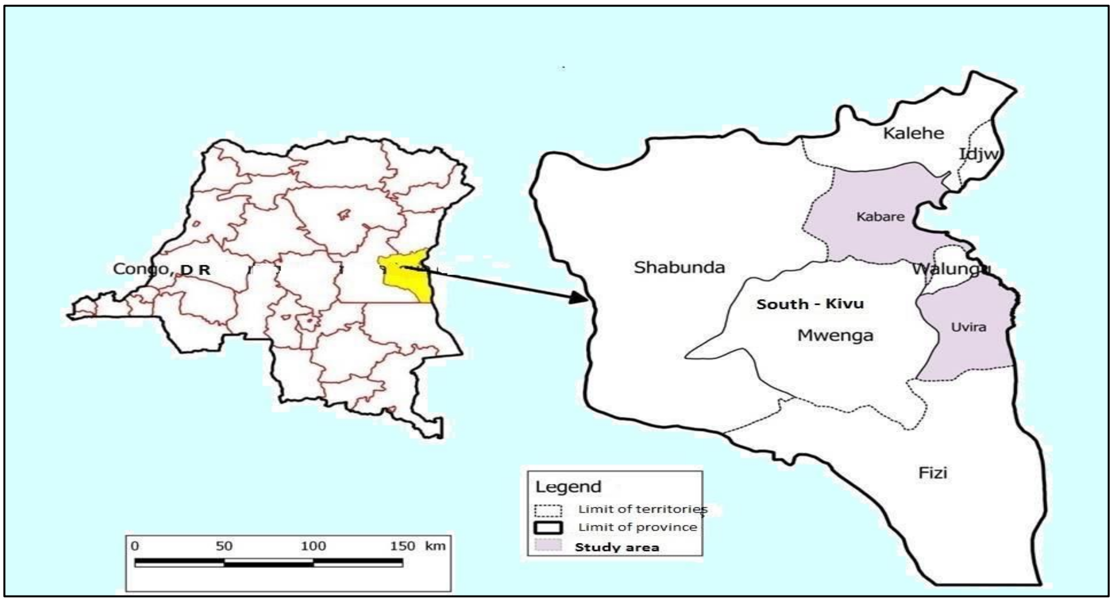

Fig. 2 A map showing the study area: Kabare and Uvira in South-Kivu.

Survey area of *Spodoptera frugiperda*

The survey of *Spodoptera frugiperda* was carried out in private fields of maize at the smallholders located in the Kabare and in Ruzizi plain located in Uvira territories of South Kivu province. Kabare is located at 2° 30' S; 28°30' E, and is 1420 m above sea level and Uvira is located between 03°20' and 4°20'S; 29°and 29°30' E , and 1000 m above sea level. Kabare is dominated by highland and it has borders with Rwanda and North Kivu province. The annual precipitation average of the study area is 1300 mm with a maximum of 1800 mm and minimum of 800 mm. The average for temperature is annually 19, 5 °C. The soil is of volcanic nature but dominated by clay. Whereas, Uvira is dominated by lowland has borders with Rwanda and Burundi. The annual precipitation average of the study area is 1300 mm with a maximum of 1600 mm and minimum of 800 mm. The average for temperature is annually 22, 5-25 °C with a maximum of 30, 5° à 32, 5 °C in September and a minimum of 14, 5 – 17 °C in July. The soil is dominated by two types: sandy clay and clay sandy (Bashagaluke *et al.*, 2015).

Experimental Site

Edaphic Condition of the Land

According to Lunze (2000), Mulungu experimental site soils are clayey, with humus horizons often thick when erosion is weak or absent. It is well supplied with organic matter and the total nitrogen content is high. It is not acidic. Phosphorus and potassium may be weak but not always. This soil has a very good production potential, but the nitrogen becomes limiting with continuous exploitation. Table 1 summarizes the characteristics of the soil of experimental site (soil samples were collected at a depth of 0 to 30 cm of soil prior to trial installation)

Table.1. Characteristics of the soil of experimental site (INERA, 2017 cited by Ntamwira *et al.*, 2017)

Site	pH water	C (%)	N (%)	Phosphorus assimilable (mg P/kg)	Exchange Complex (méq/100g)						Texture		
					Ca	Mg	K	Fe (ppm)	Al+++	H+	Clay (%)	Sand (%)	Silt (%)
Mulungu	5,17	2,74	0,31	20,71	2,83	0,72	0,38	122,2	1,83	0,70	63,81	20,91	15,29

Climatic Condition

The period of the test benefited from a precipitation distributed as follows in table (2), below

Table.2. Climatic data of Mulungu during the year 2017 (INERA, 2017)

Parameters	Months											
	January	February	Mars	April	Mai	June	July	August	September	October	November	December
T°C	23,3	23,5	23,4	23,4	23,4	22,8	22,7	23,5	24,0	23,6	23,2	23,3
P.mm	185	154	189	187	133	52	40	59	100	163	201	208

Legend T°C: Temperature, P.mm: Precipitation

MATERIALS

Maize (*Zea mays* L.) is the biological material of research survey and experimental. The maize seeds for experiment are *SAM VITA A, SAM VITA B* and *GEN* (*GV 664*) from INERA-Mulungu. The characteristics of these varieties are illustrated in Table 3.

Table.3. Characteristics of maize varieties *SAM VITA A, SAM VITA B* and *GEN*.

Maize varieties	Yield (Kg / ha)	Production cycle (months)
GV 664	1719	4
SAM VITA A	2328	4
SAM VITA B	1419	4

METHODS

Prospecting of maize plants

Phytosanitary rounding or phytosanitary prospecting (Dupriez and Simbizi, 1998) was carried out in these associations studied by the diagonal and corn observation methods. The maize plants contemplation begins after one month of cultivation and the caterpillar collection of *Spodoptera frugiperda*. The caterpillar is collected by hand along the diagonal (Dagnelie ,1992) and placed in the plastic bottle at 75 %, afterwards to the Agricultural Entomology Laboratory of Biology at the Research Center in Natural Sciences, CRSN / Lwiro. Insect collection began on March 12, 2017 for crop season B and on September 2, 2018 for crop season A; 2 times a month and every 2 weeks for treatment, for phytosanitary rounding on the two lands (low and high) and for experimental device too.

Fall armyworm Identification

Fall armyworm were recorded and identified by several specialists. However, for the first identification at the Agricultural Entomology Laboratory, Entomology Section at the Research Centre In Natural Sciences by photographs of the caterpillar (identification key) proposed by Goergen *et al.*, (2016) and a microscopic view using binocular (Leica) were used. According to the confirmation of the pest for genetic analysis, the caterpillar collection was sent to the Plant Virus Department Leibniz Institute DSMZ-German Collection of Microorganism and Cell Cultures, Germany. During the prospecting; maize plants attacked and healthy were counted.

Experimental Device

This experimentation was conducted in A and B crop seasons, from March-July 2017 (Season B) to September-January 2018 (Season A). The treatments were arranged in split-plot experiments with four replications (blocks) which are subdivided into 8 main plots. The main factor was the combination of grass shrub species and secondary factor maize varieties. The whole plots (of big plot) were split into three subplots (corresponding to the 3 maize varieties), i.e. a total of 96 subplots. Each repetition having 32 treatments. Each main parcel had a size of 10 x 10 m, ie 100 m^2 at a distance of 3 m. After plowing, manure and microdoses of NPK fertilizer were applied except for control treatment. Thus, 200 kg of cow dung, well decomposed mixed with the soil in the proportion of $\frac{1}{2}$, and to 500 g of NPK (dissolved in the water until the disappearance of the granules). Two grasses, *Pennicetum purpureum* and *Setaria barbata* and five shrubs, *Leucaena leucocephala, Calliandra calothyrsus, Albizia gummifera* and *Tithonia diversifolia* were planted in association at 1 m intervals with line spacing of 25 cm for grasses and 50 cm for shrubs.

Population Variables

The percent of infested plants (% IP) (Harrison, 1984b; Urbaneja Garcia, 2000; Diez ,2001; Murúa *et al.*, 2006) was calculated by the following equation:

$$\% \text{ IP} = \frac{\text{Infested plants}}{\text{Total plants}} \; x \;\; 100$$

Frequency (F) is the percent of individuals of certain species in relation to total individuals of all species (Canal Daza, 1993; Molina-Ochoa *et al.*, 2001; Molina-Ochoa *et al.*,2004; Murúa *et al.*, 2006), and was calculated by using the following formula:

$$F = \frac{\text{No. individuals of species "i"}}{\text{No. total collected individuals}} \; x \; 100$$

The formulae shown as follows of incidence (% I) and relative abundance (RA) were used for estimations (Berger, 1980):

$$\% I = \frac{\text{Number of Spodoptera frugiperda captureted}}{\text{Total number of sample species captureted}} \; x \; 100$$

And

$$R\,A = \frac{\text{Number of Spodoptera frugiperda captureted}}{\text{Total number of sample species captureted}}$$

Statistical Analysis

Percent of o infested plants, incidence, frequency and relative abundance data were angularly transformed and subjected to analysis with the software SigmaPlot 12.0, SYSTAT Software Inc., San Jose, CA, USA,2007 (Ludbrook, 2008). In order to determine differences between and among FAW per crop systems from the same region and those from different regions, Ficher LSD Method were performed to separate group means where ANOVA indicated significant difference ($P \leq 0.05$) (Dagnelie ,1992; Presad, 2015).

RESULTS AND DISCUSSION

Field size (m²)

The figure 3 (a) and (b) below show that the highest fields size in m^2 at Uvira -lowland (108750 ± 73180, 31) than at Kabare-highland (3218, 75 ± 4015,856) **.** ANOVA revealed a significant differences in the field size of maize among years during the period of cultivation A and B(F= 950,616; P <0.001; df= 15) .The comparison of means by Ficher LSD Method shows that Uvira –lowland has big fieds size of maize plants cultivation than the Kabare-highland. Its seasonal yields pretty much determine the food security situation in the Uvira-lowland particularly and DRC country lowland generally (Rapport National en RDC, 2009).

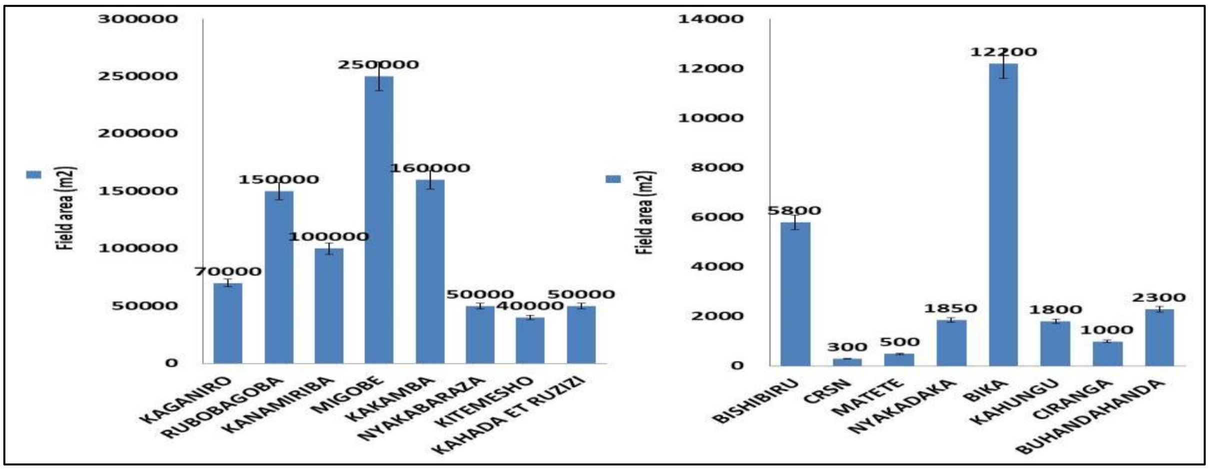

Fig. 3(a) Kabare-highland **Fig. 3(b) Uvira –lowland**

Percent of infested plants (%IP) and frequency on Kabare-highland and Uvira-lowland

The figures 4 (a) and (b) show the percent of infested plants and frequency on Kabare-highland and Uvira-lowland. The percent of infested plants (%IP) by FAW larvae and adult was higher at Uvira -lowland (91,196 %) than at Kabare-highland (6,587 %). In Uvira, 4259629 plants (3884627 infested plants and 375002 healthy plants) whereas, in Kabare, 73552 plants (4845 infested plants and 68707 healthy plants) were examined. The percentage of infested plants at Uvira was highest during period of maize cultivation (A and B), while ANOVA revealed a significant differences in the percent of infested plants of maize among years during the period of cultivation (A and B) study in Uvira -lowland area (*F= 595,458; P < 0.001; df= 15*). While the comparison by Ficher LSD Method shows that Uvira-lowland has highest infested plants of maize than Kabare- highland. In both areas, the frequency of fall armyworm are the same among years during the period of cultivation (A and B) study (*F= 0,143; P = 0,711; df= 15*). The lower infested plant in Kabare-highland agreed with those previously reported by Cagnolo *et al.*, (2002) demonstrated a decrease of certain species of insects on the altitudinal gradient. The results obtained at Uvira-lowland agreed with those previously reported by Kemp and Berry (2001) observed that high temperature and population dynamics affect the level of infestation. The fall armyworm, *Spodoptera frugiperda* is a cosmopolitan pest of the maize crop (Wiseman *et al.*, , 1966). Berry (1998), observed that the two crops are tolerant to most insect pest especially during wet season because of the profuse growth of foliage. The results obtained at Uvira-lowland agreed also with those previously reported by Willink *et al.*, (1991) for the Tucumán region, Sosa (2002) for the North of Santa Fé province, and Murúa *et al.*,(2006) for the Northwestern Argentina. Earlier plantings had lower levels of FAW infestation and damage, a response similar to that reported by Mitchell (1978), and Harrison (1984b) on corn infested by corn earworm and fall armyworm, respectively.

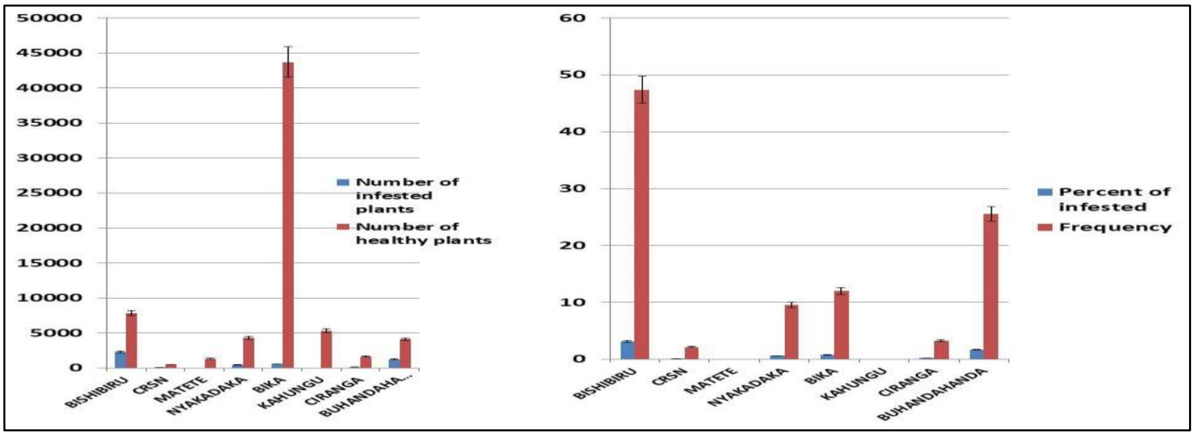

Fig. 4 (a) Percent of infested plants and frequency on Kabare-highland

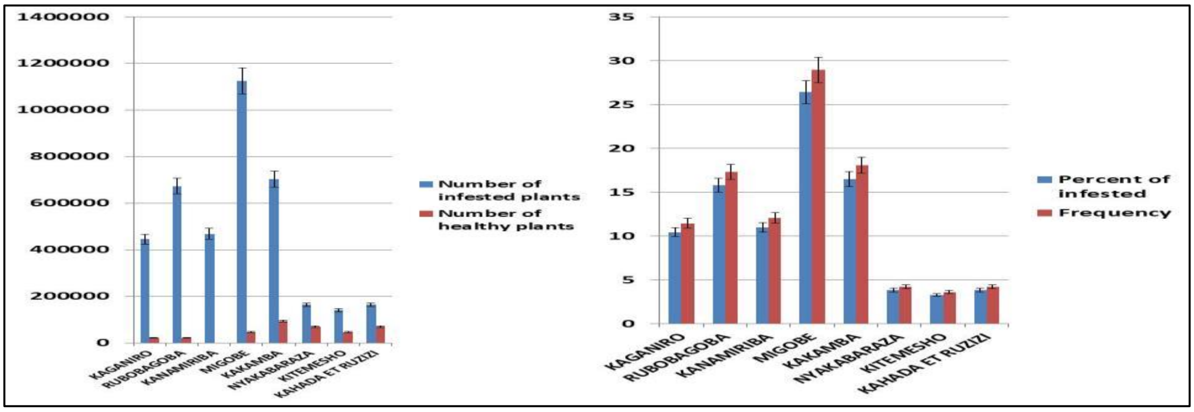

Fig. 4(b) Percent of infested plants and frequency on Uvira-lowland

Infestation of plants on A and B crop seasons

The figure 5 presented the data of infested plants by fall armyworm during the A and B crop seasons. ANOVA revealed a significant differences on infested plants of maize among years during the period of cultivation A and B (*F= 9,5 62; P =0.001; df= 23*) .The comparison of means by Ficher LSD Method shows that, on period of cultivation A plants of maize of the Agroforestry+ NPK-Manure crop system were more infested than two others crop systems (NPK-Manure and Naturel fallow), therefore on period of cultivation B plants of maize of the NPK-Manure and Naturel fallow were highly infested than the Agroforestry+ NPK-Manure crop system. The results obtained at Uvira-lowland agreed with those previously reported by Altieri *et al.*,(1978), in polycultures *Spodoptera frugiperda* (Smith) incidence as cutworm in maize was reduced 14 %. Also, these systems had 23 % less infestation of fall armyworm as whorl feeder. Altieri (1999) established that the level of internal functioning regulations in agro-ecosystems is largely dependent on the level of plant and animal diversity.

Alitude also influence either directly by the changing of weather conditions or indirectly through insect communities interactions (Hodkinson, 2005). Generally, biodiversity decreases with altitude (Nabors, 2004; Atalay, 2006). Also insect populations are affected by habitat disturbance (Atalay 2006). Kitts (2009) said that increasing incidence of stray animals has could become a major problem for crop farmers often resulting in significant losses. According to different authors, fall armyworm can be a serious pest of maize because the insects can damage the foliage, tassels, and ears (Harrison 1984 a; Ghidiu and Drake 1989; Williams and Davis 1990; Marenco *et al.*, 1992; Cruz *et al.*, 1996). However little information has been published about levels of infestation and yield losses. Marenco *et al.*, (1992), working with sweet com cultivar, concluded that fall armyworm feeding affected growth parameters such as plant height, leaf area and fresh and dry weights. According to the authors, fall armyworm densities as low as 0, 2-0, 8 larvae per plant during the late whorl stage may be sufficient to reduce yields of US No. 1 ears by 5 – 20 %. Infestation with 30 fall armyworm larvae per plant of a com hybrid resulted in extensive leaf feeding damage and a 13 % yield reduction (Williams and Davis, 1990). Morrill and Greene (1974) concluded that although early and mid-whorl infestations with fall armyworm larvae resulted in defoliation, yield of field com infested with second instar larvae was not consistently reduced. Conversely, when 20% of the plants in the mid-whorl stage of growth were infested with fall armyworm egg masses, Cruz and Turpin (1983) reported that the yield was reduced 17 %. Cruz *et al.*, (1996) found a similar result (17, 7% yield reduction) working with dent com cultivars. Harrison (1984) reported that plants at the early whorl stage and younger were preferred for fall armyworm oviposition. Plants infested early in their development were less tolerant than plants infested later. Yield reductions varied from 14, 3 to 22, 7 %.

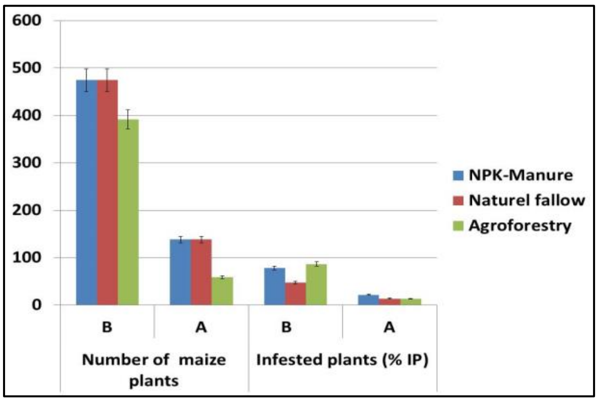

Fig. 5 Infested plants on A and B crop seasons

Relative Abundance and Frequency of Fall Armyworm

The figure 6 illustrates the data of relative abundance and frequency of *Spodoptera frugiperda* by cropping system. The figure 6 summarizes the total number of fall armyworm collected on cropping system experimental during March 12, 2017 for crop season B and on September 2, 2018 for crop season A, a total of 563 *Spodoptera frugiperda* with a high number on Manure-NPK crop system with 339, after coming the Naturel fallow crop system with 175 and at the end the agroforestry+ NPK-Manure with 49. Concerning the relative abundance NPK-Manure crop system have more important on B and A crop seasons (0,175 and 0,026) and has a high frequency (86,112 % and 13,888 %) after coming Naturel fallow crop system with 0,089 and 0,014 of abundance, 85.928 % and 9.058 % of frequency and at the end coming Agroforestry+ NPK-Manure crop system with 0,057 and 0,021 of abundance and 64,28571417 % and 35,71428583 % of frequency. While ANOVA revealed not significant differences in the frequency FAW on maize plants attacked among years during the B period of cultivation study on the both crop systems (*F=0,700 ; P= 0.508; df= 23*) and at A, period of cultivation (*F=0,881; P= 0.429;df=23*), as the abundance (*F=2,237; P=0.132; df= 23*). But, ANOVA revealed significant differences in the abundance of *Spodoptera frugiperda* on maize plants among years during the B period of cultivation study on the both crop systems , (*F=37,528; P<0.001; df= 23*). The Fisher LSD Method of comparison shows the abundance of FAW on maize plants of the NPK-Manure crop than Naturel fallow and Agroforestry+ NPK-Manure crop system, so the Naturel fallow has abundant *Spodoptera frugiperda* than the Agroforestry + NPK-Manure crop system. Many factors affect population abundance such as competition, natural enemies, and resources, but the relative contribution of exogenous and endogenous effects remains an open question for nearly all biological populations (Ylioja *et al.*, 1999). Understanding the factors that influence the distribution and abundance of an insect is a fundamental issue of insect ecology and is a practical concern with insects that cause economic damage (Baskauf, 2003). The fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) has a wide distribution, it is subjected to much climatic diversity, namely, temperature, moisture, and soil type. The environmental factors influencing development and survival, as well as genotype, agricultural practices, crop phenology, and plant maturity may contribute to the dynamics of the system in a given locale (Harrison, 1984 a; Pair *et al.*, 1986; Barfield and Ashley, 1987; Simmons, 1992; Riggin *et al.*, 1993).

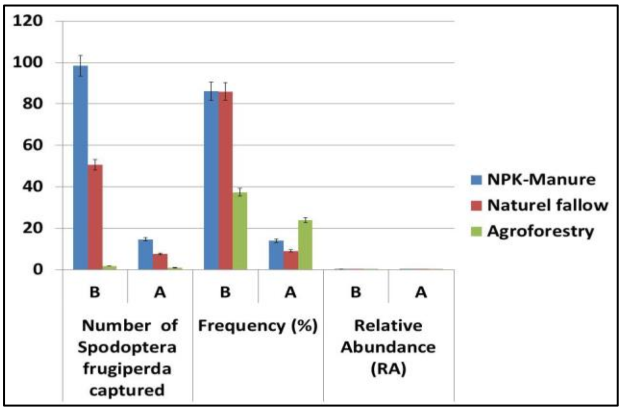

Fig. 6 Relative abundance and frequency of fall armyworm

Incidence of fall armyworm species per crop system

The figure 7 illustrates the data of incidence of *Spodoptera frugiperda* per crop system. NPK-Manure crop system have more important incidence of fall armyworm (17,4660 %) on B crop season after coming Naturel fallow crop system with 8,9994 % and at the end coming Agroforestry+ NPK-Manure crop system with 5,7036 % . While ANOVA of incidence among years during the B period of cultivation study in both crop systems showed a significant differences (*F= 46,048; P<0.001; df= 23*). The Fisher LSD Method of comparison shows the high incidence of *Spodoptera frugiperda* on maize plants of the NPK-Manure crop system among years during the B period of cultivation study in both areas than Naturel fallow and Agroforestry+ NPK-Manure crop system, so the Naturel fallow has high incidence of *Spodoptera frugiperda* on maize plants than the Agroforestry+ NPK-Manure crop system too. Among years during the A period of cultivation study in both crop systems, ANOVA revealed not significant differences in the incidence of fall armyworm on maize plants (*F=2,237; P= 0,132; df =23*). Silvain *et al.*, (1981) show that the *Mocis latipes* apparitions took place at the period when population density of *Spodoptera frugiperda* was maximal, the dry season. Among years during the A period of cultivation study, the incidence of fall armyworm on maize plants was no important. Silvain *et al.*, (1981) demonstrated that the *Spodoptera frugiperda* population doesn't growing up on the returning rain and vegetation of middle-November. Litsinger and Moody (1975) described the status of integrated pest management in multiple cropping systems, including some examples of the behavior of insect pests in mixed and strip cropping systems. They ascribe the regulation of insect pests in polycultures to physical interference (protection from wind, hiding, shading, alteration of color or shape of the stand) and to biological interference (production of adverse chemical stimuli, presence of predators and parasites). One important biological feature of multiple cropping is its increase in diversity of both the flora and the fauna (Raros, 1973). One hypothesis frequently used to explain smaller herbivore populations in complex environments (i.e. polycultures) is that predators and parasites are more effective in this situation (Root, 1973). In experimental conditions diversity and activity of natural enemies have been higher in monocultures than in polycultures, mainly due to migration of agents from diversified plots, and a marked concentration of preys and hosts in monocultures (Pimentel, 1961; Root, 1973).

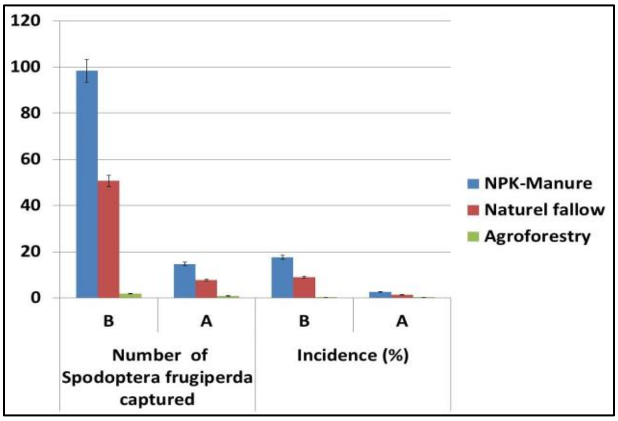

Fig. 7 Incidence of fall armyworm

Spodoptera frugiperda collection plan design per man-day during both cropping seasons A and B

Table 4 : Shows the number of people who collected and killing *Spodoptera frrigiperda* when maize have 50 cm height

Table 4 Number of caterpillar and Man –Day, cost of picking per treatment per ha.

Treatments	**Crop systems**	**Number of caterpillars**	**Man-Day**	**Cost ($ USA)**
T0*	**NPK-Manure**	11300	28	26,3
Control	**Naturel fallow**	5830	25	23,4
T1 (*Leucaena* + *Calliandra* + *Pennicetum* + NPK-Manure)	**Agroforestry + NPK-**	470	5	4,7≈5
T2 (*Leucaena* + *Albizia* + *Pennicetum* + NPK – Manure)	**Manure**	200	6,3≈6	5,9≈6
T3 (*Albizia* + *Leucaena* + *Setaria* + *Pennicetum* + NPK- Manure)		220	6,3≈6	5,9≈6
T4 (*Leucaena* + *Calliandra* + *Setaria* + *Pennicetum* +NPK- Manure)		60	6,3≈6	5,9≈6
T5 (*Leucaena* + *Setaria* + *Pennicetum* + NPK- Manure)		170	8,3≈8	7,8≈8
T6 (*Calliandra* + *Leucaena* + *Pennicetum* +*Tithonia* + NPK- Manure)		130	7,5≈7	7,0

The table 3 above, shows that 28 men-day could pick up a number of 11300 FAW for 26, 3 $ USA on the NPK-Manure crop system but, at Natural fallow, 25 men-day a number of 5830 caterpillars for 23, 4$ USA. Agroforestry + NPK-Manure is the benefic crop system therefore using few men-day (5 to 8) and cost (5 to 8$ USA). This crop system constituted the barrier of attack therefore the few number of caterpillars FAW (60 to 470) could restore soil fertility and supply fodder for livestock. Then, family of four peoples, respectively two parents and two children are skilled at picking up the caterpillars, *Spodoptera frrigiperda* during four hours a day time in one hectare of size on the intercropped corn at an interval of 1 m x 50 cm. These systems can more efficiently fill a microclimatic niche, and more efficiently use each unit of land area (Iggozurike, 1971; Altieri *et al.*, 1978). Polycultures are defined by Hart (1974) as systems in which two or more crops are simultaneously planted within sufficient spatial proximity to result in interspecific competition and complementation. These interactions may have inhibitory or stimulating effects on yields, and depending on these effects polycultures can be classified as amensalistic, comensalistic, monopolistic and inhibitory (Hart, 1974). In the design and management of these systems, one strategy is to minimize negative competition and maximize positive complementation among species in the mixture (Francis *et al.*, 1976). In the tropics, polycultures have been an important component of small farm agriculture, and one of the reasons for the evolution of these cropping patterns may be fewer incidences of insect pests (Francis *et al.*, 1976 and 1977a; Altieri *et al.*, 1978). According to Holdridge (1959) and Dickinson (1972), the most rational agricultural system for the tropics is that which most closely simulates the energy flow and structural characteristics of diverse natural tropical ecosystems. They conclude that monocultures are ecologically unsound and are not sustainable for the long-term social and economic well-being of small farmers.

CONCLUSIONS

In the current study, it was observed that the percentage of infested plants at Uvira-lowland was highest during period of maize cultivation, the physics and the populating climatic characteristics have an impact on the land. FAW were infested all crop systems Agroforestry+ NPK-Manure, NPK-Manure and Naturel fallow. The incidence of fall armyworm (FAW) on maize plants was no important on Agroforestry+ NPK-Manure crop system, but highly on two others crop systems, NPK-Manure and Naturel fallow. The FAW were abundant on NPK-Manure and Naturel fallow crop systems too. Agroforestry + NPK-Manure is the benefic crop system therefore using few men-day (5 to 8) and cost (5 to 8$ USA). This crop system constituted the barrier of attack therefore the few number of caterpillars FAW (60 to 470) could restore soil fertility and supply fodder for livestock.

It is recommended that this research continue and the results on polycultures (Agroforestry) be incorporated into modem pest management systems. In addition to selecting the most appropriate crop diversity, researchers should explore strategies for pest control in conjunction with agronomic research to maintain acceptable yields. It is critical to develop new and high yielding cropping patterns without creating conditions that favor new and equally high potentials for pest damage. Many monoculture systems promote these pest problems. The adoption of multiple cropping is not appropriate to all zones nor all scales of farming due to high labor requirements and reduced production of particular crops. These systems are especially important to the small farmer in the tropics of the world, and some research must be directed toward improving these systems with elements of the available new technology.

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Availability of data

The datasets supporting the conclusions of this article are included within the article (and its additional files).

Authors' contributions

JAKR, HMB and JBN participated in the design of the study, conducted the experiments, JARK prepared the manuscript, and performed the statistical study. JAKR and JBN helped to improve this paper. NG made the map of study area. JARK, contributed to this study design. All authors read and approved the final manuscript.

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