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Host range and distribution pattern of *Dacus punctatifrons* and *Helicoverpa armigera* : two fruigivorous pests; elucidation of interspecific competition in tomato's agro-system

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Key words: Pest, host spectrum, clumped distribution, overlapping, cohabitation.

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Abstract

With the aims to use the integrated pest management approach to control *Dacus punctatifrons* and *Helicoverpa armigera* two pests of tomato, knowledge on their ecological requirements is crucial. Three years survey was done in tomato gardens, orchard, farm and virgin lands to record infested fruits. Collection sites were noted, potential infested fruits were incubated and the emerged insects identified. The number of infested fruits caused by each of the pest species was recorded monthly. The variance-to-mean ratio (VMR) where used to determine the distribution model of pests in control gardens. Of 40 plant species examined, 5 species belong to 2 families that hosted *D. punctatifrons* maggots while 23 species belong to 11 families that hosted *H. armigera* caterpillars and 9 species were exempted of pest attacks. The pests were continuously distributed in the 14 explored localities of the 4 regions of Cameroon. A VMR factor showed that, larvae populations presented a clumped distribution on their hosts ($D > 1$). This can be the fact that female laid their eggs on bunched fruits. The pest's impact significantly varied with plant varieties, exotic tomato was more susceptible to the pests than the local variety. As result of competition, the pests' populations responded to their patchy distribution by separating their periods of resource exploitation. This separation can also be the fact of climate, because the overlapping of populations' larvae were synchronized with change in seasons and was observed at the same period over the years.

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Introduction

Tomato, *Lycopersicon esculentum* (Solanaceae) is one of the most important vegetable crops widely grown in the world for its nutritional, medicinal and economic value (Grubben and Denton, 2004).

Tomato exceeds all other vegetables with its total contribution to human nutrition because it is consumed in great quantities and in various ways (Grubben and Denton, 2004). Majority of people in the developing countries including Cameroon are engaged in tomato production, but with low productivity mainly due to insect pest which attacks fruits. White and Elson-Harris (1992) contributed to the knowledge of host plant records for the major pests of Afrotropical area, but host/pest relation is a dynamic relationship and it imposes constant updating of pest plant host list (Novotny, 2005). *Dacus punctatifrons* Karch, 1887 (Diptera: Tephritidae) and *Helicoverpa armigera* Hübner, 1808 (Lepidoptera: Noctuidae) are among pests that severely attacked tomato in Cameroon.

The study of their ecology has received so little attention in our study area. Amongst these species infesting fruit, some are specific to one host, while others feed indiscriminately on many host families (White and Helson Harris, 1992). *D. punctatifrons* and *H. armigera* have been described by several authors as pest insects of many crops De Meyer *et al.* (2001) and wild plant species. Djiéto-Lordon and Aléné (2006) noticed that these two insects are the major tomato pests in Cameroon and are the principal break of tomato farming.

Amongst the present insect pests, some species have been transported and introduced into many parts of the world, but very few became invasive in their introduced area (Duyck *et al.*, 2008). He also mentioned that invasive species always occurred in areas where, most of the time, other species (being indigenous or previous invaders) were already present. The new invaded species and the indigenous ones feed some time on the same plant host. Due to this same trophic habit, inter-specific competition frequently occurs between the invaded species and the resident ones particularly when they feed on the same part of the plant. Sometimes, modifications of the host plant of certain species are observed. Numerous cases of species displacements attested for the occurrence of inter-specific competition, particularly after invasions (Duyck *et al.*, 2004).

In the present study the larvae of *Dacus punctatifrons* which is an indogenous species and *H. armigera* an exotic species are sharing the tomatoes' fruits as their food. If *H. armigera* is an exotic pest, *D. punctatifrons* is native to tropical humid areas, where it was primarily known to feed on wild tomatoes and cucurbits (White and Helson Harris, 1992). Since 1999, Tindo and Tamo were the first to report that *D. punctatifrons* is an important pest of tomato in, Lekié Division. Recently, Ntonifor and Okolle (2006) pointed out *D. punctatifrons* on tomato in Fako Division. *Dacus* species are distributed throughout tropical and sub-tropical rain forest of the world and appear to be endemic to these areas (Drew, 2004).

In addition, White and Elson-Harris (1992) reported Dacus as an Afrotropical genus although a few species are also paleotropical and subtropical. Virgilio *et al.* (2009) reported the presence of the flies in six tropical countries (Cameroon, Congo, Benin, Kenya, Uganda, and Zimbabwe). White and Elson-Harris (1992) referred to these flies as 'rare species' which sometimes attack cultivated crops (mainly cucurbits) and with a narrow host range. On the contrary, *Helicoverpa armigera* is an exotic introduced species to this study area. It was first reported in Hungary Northern Europe and it is now widespread in all the countries (Trowell *et al.*, 2000).

This pest was recognized by Mehta *et al.* (2010) in Northern India as the main pest of tomato with more than 70% of fruit loss. In Africa this Lepidoptera was long known as a pest of cotton (Silvie *et al.,* 1989). Djiéto-Lordon and Aléné (2006) noticed this Lepidoptera as important tomato pests in Cameroon. The work of Heumou *et al.* (2015) clearly characterized *Dacus punctatifrons* and *Helicoverpa armigera* as the major pests of tomato in the Western Highland and Southern Plateau of Cameroon.

These two insects being the pest of the same host, competition might occur. It is widely recognized that when members of different species compete for a resource, one species may be forced to move or become extinct, or the two species may share the resources and coexist (Barbault, 1997; Miller and Harley, 2007; Manuel and Molles, 2008; Duyck, 2008). Knowing that *H. armigera* is a nonnative pest, whereas *D. punctatifrons* is a native one, this insect-insect relationship may bring new information on their Ecology.

The study aimed to: identify the host plants of these sympatric pests of tomato, to study the spatio-temporal distribution of the pests in their hosts, to discuss the relationship between pests/host and among the pests with emphases on their cohabitation strategies. This knowledge constitutes an important stage that may lead to a better pest management in tomato agro-system.

Material and methods

Site localisation

This study was carried out in the humid zone of Cameroon situated in 4 Regions (Centre, Littoral, West and North-West), 14 localities were investigated from March 2012 to December 2015. They are located between 09° 40'-12° 25' longitude and between 03° 42'-6° 415' latitude. The altitude varies from the lowlands 200 m to highlands around 1500 m. These study sites have different climatic conditions. The Centre region has forest vegetation with four seasons two rainy and two dry seasons; the Littoral has forest vegetation with two seasons a long rainy season and a shot dry season, West and North-West have savanna vegetation with two seasons a long rainy season and a shot dry one. Priority was given to these regions because of the previous studies carried out there and because they are amongst the oldest area where gardening is practiced in the country (Westphal, 1981).

Host plant identification

Over three years gardens, farm lands and virgin lands in and around our study areas were visited. Potentially infested fruits were observed. They were harvested from the trees and also fresh fruits found on the ground were picked. Samples of infested fruits (identified by the puncture holes made by laying insects) were collected, taken to the laboratory and placed into a closed plastic container laid with sand. After some days larvae develop to form pupa from where the adult *D. punctatifrons* would emerge. After their emergence adults *D. punctatifrons* were counted. The plants hosted caterpillars of *H. armigera* were, directly observed on the field, because of their large size they were visible and easy to identify. The parts of the plant showing traces of infection were noted and then for infested plants that could not be identified, its part was collected and taken to the National herbarium in Yaoundé, Cameroon for identification purposes. For each plant and (or) fruit that was identified or collected, the geographical co-ordinates were taken with a GPS. From the incubations, we drew up a list of the other pests that emerged from the fruit.

Spatial distribution of pests

In other to determine the host range and distribution of pests, a random observation on different regions and informal discussions with the farmers was conducted by our working team to identify infested sites within our study area. For each infested sites the GPS location, latitudes and longitudes were taken.

The data were then analyzed using software Map info. 8.4 to produce distribution charts. Locations of insects were mapped in Universal Transverse Mercator (UTM) coordinate and were converted to latitude and longitude.

Study of spatial distribution of individuals was limited in our experimental gardens, where the tomato variety "Rio Grande" were cultivated. The gardens were divided in to quadrats of 1m². In each of the garden, 12 quadrats were randomly selected to carry out the experiment; each quadrat contained 4 plants of tomatoes. After dissection of infested fruits, all the larvae from fruits of the same quadrats were counted. The ratio of Variance/Mean of the number larvae obtained per quadrat was used to evaluate the distribution index of infected fruit of each pest on the two sites.

Relationship between pests/host and among the pests

The interactions between pests and their host and amount the two pests were observed in the main study sites of Noun valley, precisely Koutaba situated at 05°38'47.9''N; 010°48'22.2''E, altitude: 1186 m, in the Western savanna of Cameroon.

The unimodal rainfall regime is dominant her (whit the mean rainfall being 130.04 mm in 2012 and temperature mean value being 18.66 °C). It was restricted in a plot of 50 m on 50 m.

Insect/host relationship

The biological material was made up of two varieties of tomato of which an exotic, « Rio Grande » (Fig. 1A) and a local variety, cherry tomato collected at Okola (Fig. 1B). The seeds came from the local fruits and from the firm « Technisem », marketed in Cameroon by the company « Tropicasem ».

To study the relationship between the pest and their tomato host, the activities of insects in the garden were observed and noted as the first fruits appeared. Equally the impacts of the pests on their host were evaluated following the protocols of Djiéto-Lordon and Aléné (2006), Vayssières (2002) and Heumou *et al.* (2015). The yield loss due to a given pest (T_{xi}) was calculated by the following equation.

$$Txi = \frac{ni}{N} \times 100.$$

Where (*ni*) is the number of fruits attacked by this pest, (*N*) the total number of fruits obtained with the whole harvest.

Insect/insect interaction

The study of the pest activities evolution was done in Koutaba where tomatoes are regularly cultivated. The insect's interactions were analysed base on the evolution of the two populations within time. The number of infected fruits caused by each of the pest species were collected and recorded on monthly bases. To avoid biases coming from quantities of fruits production per months the percentages of infested fruits were considered and were computed per month.

The collection of fruits was carried out over three years following the different seasons.

Then the monthly percentage of infested fruit by each pest was used to set curves of pests' evolution. Data on rainfall and seasons were taken from the Meteorological centre of the airport of Koutaba.

Identifications were done with several identification keys: Nonveiller Guido (1984); Delvard and Aberlenc (1989); Borror *et al.* (1976) for families and some genus of insects; White and Elson-Harris (2004) for fruit flies. These identifications were confirmed by the taxonomists of the faunistic laboratory of CIRAD (Montpellier).

Statistical analysis

The Geostatistical software of Map Info was used to draw the map of pest distribution. The distribution index (D) or Fono factor were computed using the ratio of the variance to the mean,

Equation $D=\delta^2/\mu$ (δ^2= Sample variance, μ =Sample mean).

The comparison of infestation rate amount the pests and the varieties were done by a General Linear Model. The evolutions of the infected fruits caused by the two populations were compared monthly using spearman's correlation of SPSS 17 software at the significant level of ($p \leq 0.05$).

Results

1-Host spectrum

D. punctatifrons does not have a large host spectrum it is the pests of 5 fruits species of cultivated plants and wild tomato species belonging to 2 Families. The larvae feed exclusively on the fruits (Table 1).

Table 1. Host plants of *Dacus punctatifrons* (Karch) in Cameroon 2012-2015.

Families	Plant species	Common Names	Target organs
Solanaceae	*Lycopersicon esculentum*	Tomato	A
Cucurbitaceae	*Cucumis sativus*	Cucumber	A
	Cucubita mouchata	Melon	A
	Cucumis melo	Water melon	A
	Cucumeropsis mannii	Egusi	A

Capital letter = plant organs targeted by the pests. A=fruit.

In contrast, *H. armigera* feed on more than 23 plant species belonging to 11 Families. The larvae generally feed on leaves and flowers at younger stages and at old age on the fruits. Amongst these plants, 23 are cultivated plants and only 3 are wild plant species. Among the cultivated plants, 22 are gardening crops and only one of is a cash crop.

This makes this pest to be considered as the most dangerous pest in garden (Table 2).

Table 2. Host plants of *Helicoverpa armigera* (Hübner) in Cameroon 2012-2015.

Plant families	Plant Names	Common Names	Target organs
Solanaceae	*Lycopersicon esculentum*	Tomato	A,B,C
	Capsicum annuum	Pepper	A
	Solanum aethiopicum	Eggplant	A
	Solanum macrocarpon	Eggplant	A
	Physalis sp.	/	A,C
Cucurbitaceae	*Cucumis sativus*	Cucumber	C
	Cucubita mouchata	Melon	C
	Cucumis melon	Watermelon	C
	Cucumeropsis mannii	Egusi	C
Malvaceae	*Albelmonchus esculentum*	Okro	A
	Hibuscus gombo	Okro	A
	Corchorus olitorius L.	Wild jute	C
	Gossipium hirsutum	Cotton	A
Lauraceae	*Amaranthus viridus*	/	A
	Amaranthus esculentus	Follon	A
Fabaceae	*Phaseolus vulgaris*	Bean	A
	Glycine max	Soya bean	B
Bracicaceae	*Brassica oleracea*	Cabbage	C
Lactucaceae	*Lactuca sativa*	Lettuce	C
Liliaceae	*Alluim ampeloprasum*	Leek	B
Poiceae	*Zea mays*	Corn	A,B,C
Oxalidaceae	*Oxallis barrelieri*	/	B,C
Labiaceae	*Ocimum basilicum*	Cotimadjo	C

Capital letters = plant organs targeted by pests. A=fruit, B= flower, C= leaves.

Also, 9 other pests were noted from the different fruits explored. Amongst them three other important pest of tomato like *Dacus bivitattus*, *Chrysodexis chalcites and Tuta absoluta* (Meyrick) were found. Also a notorious pest *Tuta absoluta* was observed in some tomato farm for the first time in North-West and West regions in December 2015. This newly introduced pest infests tomato drastically with 100% of leaves and fruits attack.

These are potential competitors of *D. punctatifrons* and can partially explain the constant switching of pests from one fruit species to another (Table 3).

Table 3. Other fruit pests obtained when incubating the different fruits in Cameroon 2012-2015.

Pest Species	Host plant Species	Plant Families	Common names	Target organs.
Dacus bivittatus (Birgot)	*Lycopersicon esculentum*	Solanaceae	Tomato	A
	Cucumis sativus	Cucurbitaceae	Cucumber	A
	Cucubita mouchata	Cucurbitaceae	Melon	A
	Cucumis melo	Cucurbitaceae	Water melon	A
	Cucumeropsis mannii	Cucurbitaceae	Egusi	A
Dacus ciliatus (Leow)	*Cucubita moschata*	Cucurbitaceae	Melon	A
Bactrocera invadens (Drew *et al.*)	*Citrus sinensis*	Rutaceae	Orange	A
	Citrus grandis	Rutaceae	Grapfruit	A
	Psidium guajava	Myrtaceae	Guava	A
	Manguifera indica	Anacardiaceae	Mango	A
	Solanum macrocarpon	Solanaceae	Djakatu	A
	Solanum aethiopicum	Solanaceae	Egg plant	A
Ceratitis anonea (Graham)	*Manguifera indica*	Anacardiaceae	Mango	A
	Psydium goyava	Olacaceae	Guava	A
Ceratitis capitata (Wiedermann)	*Capsicum annuum*	Solanaceae	Pepper	A
	Capsicum frutescens	Solanaceae	Pepper	A
	Solanum macrocarpon	Solanaceae	Egg plant	A
	Solanum aethiopicum	Solanaceae	Egg plant	A
Ceratitis spp.	*Annona senegalensis*	Annonaceae	/	A
Dacus spp.	*Vernonia galamensis*	Composeae	Suite bitter live	B
Tuta absoluta (Meyrick)	*Lycopersicon esculentum*	Solanaceae	Tomato	A,B
Chrysodexis chalcites	*Lycopersicon esculentum*	Solanaceae	Tomato	A,B

Letter in capital = plants organs targeted by the pests. A=fruit B= flower.

Many other fruit plants that were found on and around the study area during the study period were exempted of pest attacks (Table 4).

2- Distribution of pests

The two pests were sympatric in all the sites visited. They have a large home range from the lowland forest that is around 200m in altitude to the Highland that is around 1500m in altitude.

All the different prospected tomatoes gardens of the humid zone of Cameroon were positive to these pests, and surprisingly shared tomato fruits in all the different sites (Fig. 2).

Table 4. Fruit exempted from insect infestations in Cameroon 2012-2015.

Plant species	Families	Common Names
Carica papaya	Caricaceae	Papaya
Averrhoa carambola	Oxalidaceae	Carombole
Irvingia gabonensis	Irvingiaceae	Bush Mango
Vitellaria paradoxa	Sapotaceae	Karite
Musa sp.	Musaceae	Banana
Ananas sativus	Bromeliaceae	Pineapple
Ficus Sp.	Moraceae	Fig
Ceiba pentandra	Bombacaceae	Casimanga
Voacanga africana	Apocynaceae	/

The result comparing the distribution of these pests in their host in the forest and in the savanna area showed that the ratio of Variance/Mean >1. The value of the Distribution index was respectively D= 27.31 for *D. punctatifrons* larvae and D= 22.5 for *H. armigera* larvae in Okola and D= 24.65 and D=11.73 in Koutaba for *D. punctatifrons* and *H. armigera* larvae respectively (Table 5). These results show that the larvae of the two pests have a clumped distribution on their host on the two study sites.

Table 5. Distribution model of different populations of *D. punctatifrons* and *H. armigera* larvae in both Okola and Koutaba in 12 randomly selected quadrats of the two study sites.

Quadrats	Sites			
	Site 1: Okola		Site 2: Koutaba	
	D. punctatifrons	*H. armigera*	*D. punctatifrons*	*H. armigera*
A	83	9	12	3
B	57	12	20	3
C	57	0	33	4
E	33	0	44	19
F	6	0	42	24
G	66	0	73	11
H	10	40	75	12
I	82	35	75	12
J	50	50	5	33
K	0	66	16	44
L	0	25	2	36
M	7	38	1	44
Sample Mean, μ	37.58	22.92	33.17	20.42
Sample variance, δ	1026.45	515.72	817.97	239.54
Ratio of sample variance to sample Mean, D=δ²/μ	27.31	22.5	24.65	11.73

3- Relationship between pests and their hosts and amount the pests

Relationship between pests and their hosts

Pests and their host interact in many ways; firstly the tomato fruits are breeding site for *D. punctatifrons* and *H. armigera* larvae and at the same time constitute their source of food. Different behaviors of gravid female were also observed: the oviposition periods and the oviposition sites were different. *D. punctatifrons* laid their eggs during the day time and directly within early green tomato fruits, while *H. armigera* laid theirs at night on the leaves and the stems of the tomato. It is after hatching that the stage 1 caterpillars move to the tomato fruits. For these two pests only the larval stages cause damage to tomato fruits. The intensity of that relationship was quantified by evaluating the damage cause by the insects on their host. The results reveal that, the impacts observed on the tomato fruits are the fact of several insects; these species were implicated at different degree and was different on the two tomatoes varieties. The test of comparison of infestation rate done by a GLM showed a very high significant difference between the attack rate of the various insects on the Rio Grande variety χ^2 =63.10 ; df=5; p<0.0001. Idem on cherry tomato χ^2 =24.40; df=5; p<0.0001. Only two species *D. punctatifrons* and *H. armigera* can be consider as tomato pests.

These attacks rates vary from a species of pest to another and also vary according to the tomato's variety.

On the Rio Grande variety, the attack rate of *D. punctatifrons* is 31.28% and that of *H. armigera* of 24.52%. On the Cherry tomato variety, the attack rate of *D. punctatifrons* is 14.29% and that of *H. armigera* de 12.42%. Finally other insects like *Chrysodeixis chalcites, Spodoptera litoralis* and *Neosilba* sp. rates of attacks were inferiors to 3% (Table 6).

Table 6. Variation of the attacks rates of pests on two varieties of *Lycopersicon esculentum* at Koutaba.

Site	Tomato varieties	Insect species							χ^2
		D. punctatifrons	*H. armigera*	*C. chalcites*	*S. litoralis*	Others	*Neosilba* sp.	Total	
Koutaba	Rio Grande	1106 (31.28)^{a}	867(24.52)^{a,b}	10 (0.28)^{b,c}	11 (0.31)^{b,c}	0 (0.00)^{b,c}	14 (0.40)^{b,c}	2008 (56.79)	χ^2 =63.10; df=5;p<0.0001***
	Cherry tomato	115 (14.29)^{a}	100 (12.42)^{b,b}	4 (0.50)^{b,b}	23 (2.56)^{b,b}	10 (1.24)^{b,b}	0(0.00) ^{b,b}	252(31.30)	χ^2 =24.40; df=5;p<0.0001***
	χ^2	χ^2 =0.23; p=0.63	χ^2 =5.75; p=0.02	χ^2 =1.22; p=0.27	χ^2 =1.34; p=0.25	χ^2 = 1.11; p=0.29	χ^2 =2.07; p=0.15	χ^2 =2.31; p=0.13	

The values put between brackets represent the infestation rate. The different letters indicate the significant differences following the pair comparisons between the varieties. p>0.05= non-significant; p<0.05 = significant;*** indicate the highly significant differences to the level of 5%.

Relationship amount the pests

The rate of infested fruits by *D. punctatifrons* and *H. armigera* varied between months, seasons and years. The curves of fruit damaged evolution showed that at the beginning of rainy season that is March, fruit infested by *D. punctatifrons* started increasing up to the peak of 70% collected per month in September, and from mid-November, this infestation decreased down to 2% in December 2012. The same cycle restarted the year after. Contrarily, the infestation of *H. armigera* have two peaks per year, the smallest in July and the biggest between November and December after the infestation of *D. punctatifrons* have dropped. By the end of November, the infestation of *H. armigera* increase up to a peak of 44% of infested fruit collected per month, between December and January.

Fig. 1. Varieties of *Lycopersicon esculentum* presenting mature fruits: (a) Rio Grande and (b) cherry tomato.

The first overlapping of the two curves occurs in the month of November and the second in March, and the same cycle stated again the year after. This overlapping of curves occurred at the same period in the years 2012, 2013 and 2014 following the seasons of the study site (Fig. 3). This overlapping of population is confirmed by the Spearman's correlation test which showed a strong negative and significant correlation between the percentage of fruits infested by *H. armigera* and the percentage of fruits infested by *D. punctatifrons* R=- 0,784; P= 0,007; N=24. That is a perfect inverse relationship between the two (Fig 3).

Discussion

Drew (2004) mentioned that most pest species are polyphagous in their native rainforest habitat, breeding in a large number of plants species in many plant families. *D. punctatifrons* is an exceptional pest.

It feeds on a narrow host range, two families of plants hosting (Solanaceae and Cucurbitaceae). Ntonifor and Okolle (2006) noticed this pest only on *L. esculentum* and *Cucumis melo* in the South West of Cameroon.

But it seems like when the two families of hosts are present, the pest prefers tomato fruits.

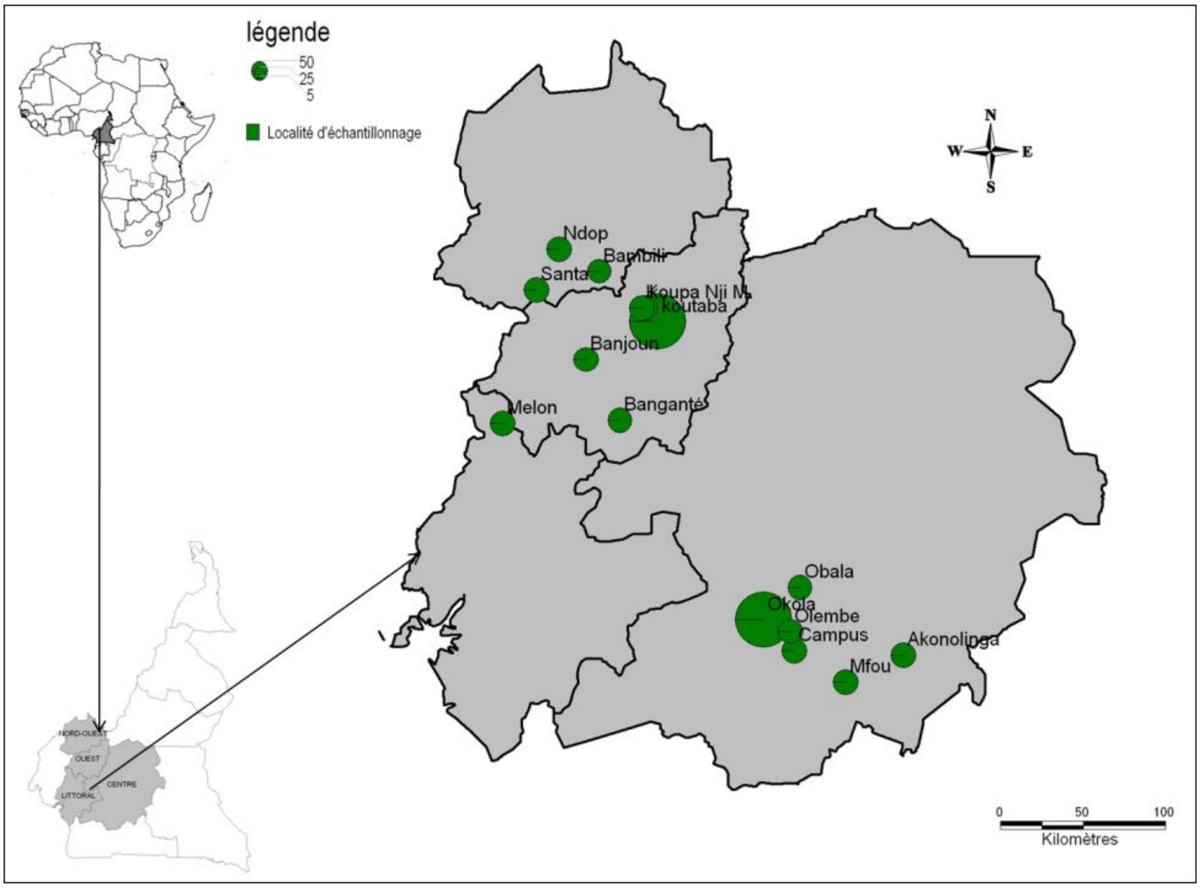
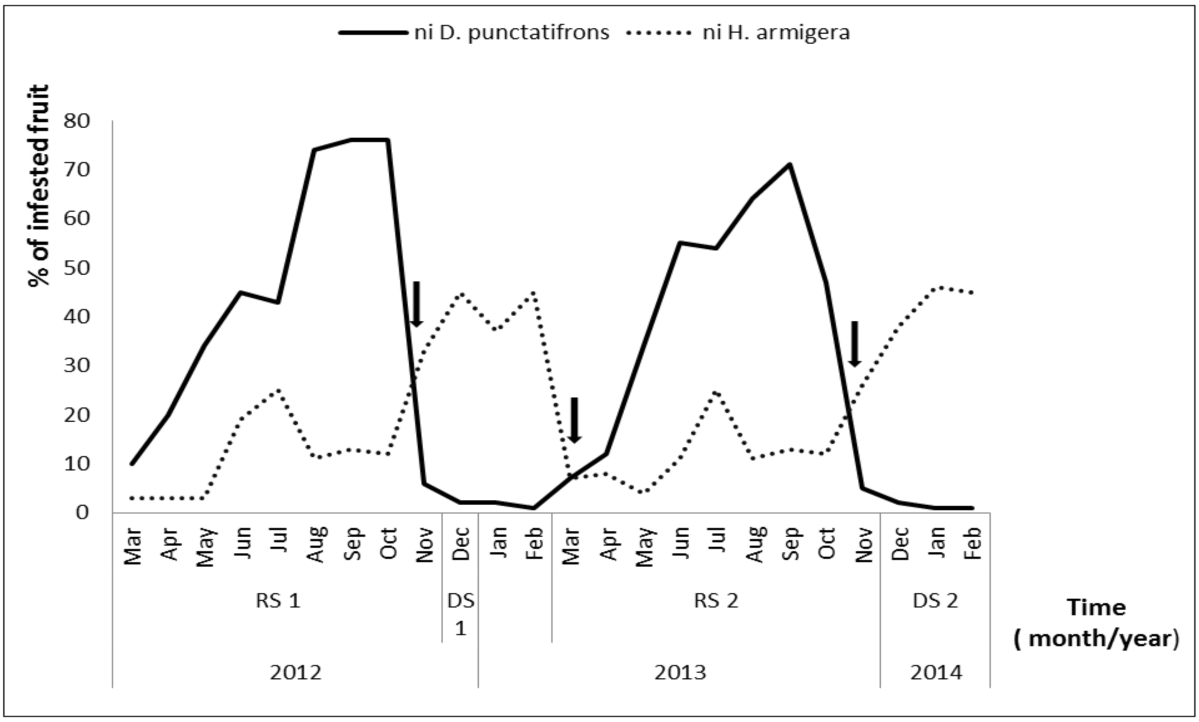


Fig. 2. Fruit collecting sites and repartition of the two principal pests of tomato in southern Cameroon.

It is important to mention that *D. punctatifrons* is the oldest pests known on tomato; that can partially explained why they are still abundant than it competitor on tomatoes. *H. armigera* is also a polyphagous pest; it feeds on more than 11 families of plants in the study area. This work mentioned for the first time *H. armigera* as pest of beans *Phaseolus vulgaris,* eggplant *Solanum Macrocarpon*, *Solanum aethiopicum,* and fresh corn *Zea maïs*. This clearly confirms that this non-native species is increasing its host spectrum and is becoming invasive in our study area.

Some others fruits plants of the site were exempted of pest attacks. This can be considered either as empty niches. In this case, fruits do not have good nutritive substances, or due to evolution, the plants have developed resistant systems to push back their pests; moreover, these fruits could still to be colonized by pests coming from the feeding-switching effect of an existing pest or a new invasive pest that could be introduced. Erbout (2010) explain that some plant hosts are also able to react to the attacks of the pest by producing some pheromones that can attract or repel the pests.

If *D. punctatifrons* is native, in central Africa forest, *H. armigera* is exotic. *H. armigera* was known in the forest part of the country, and also in the Far Nord as serious pest of cotton capsules. It is more cosmopolitan, its presence has been noticed by Silvie *et al.* (1989) in Tchad on cotton. In West Africa, the same authors also describe *H. armigera* as pest of cotton in Togo in 1993. Their presence was also mentioned in southern Europe particularly in Spain by Moral Garcıa (2006), in Hungary northern Europe where the pest was found for the first time (Trowell *et al.*, 2000). The great capacity of individual distribution (they can fly on a distance of more than 100 Km ≈ 62.5 mile) and the international cotton trade may have favoured their spread. Furthermore, the capacity of *H. armigera* larvae to move from one fruit to another and absence of a specific natural enemy in our study area are characteristics of their life history that favour them to easily adapt to new environments. The results also showed that within the study area, *H. armigera* and *D. punctatifrons* were found in the entire sites from Central, Littoral, Nord-West and West Regions of Cameroon. That is from the lowland forest to the highland savanna (200-1500 m altitude), even though this altitudinal gradients involved different climatic conditions such as vegetation, temperature and rainfall.



RS= rainy season; DS=dry season, ni=relative abundance.

Fig. 3. Dynamic of competitive populations with a triple overlapping between the infestations of *D. punctatifrons* and *H. armigera* in 24 months at Koutaba Cameroon 2012-2014.

The result revealed that *D. punctatifrons* and *H. armigera* tolerate all these range of climatic conditions, Brown (1984) mention that tropical species are limited more by biological factors than physical factors. *D. punctatifrons* was earlier mentioned by Tindo and Tamo (1999) in Lékie as pest of cultivated tomato that was the area of first detection in Cameroon. Ntonifor and Okolle (2006) have also noticed the harmful effect of *D. punctatifrons* on tomato in the South-West Region of Cameroon. Ngamo Tinkeu *et al.* (2010) notice the presence of *D. punctatifrons* in Ngaoundéré Adamaoua Region of Cameroon. This pest seems not to increase its spatial distribution, it is just enclosed to central African forest which is it native area and has not been mentioned elsewhere in the world (according to exploited documents). Withe and Elson Harris (1994) described the family Tephritidae as associated to Afro-tropical forest only. Virgilio (2009) mentioned this pest in central African forest countries: Congo, Benin, Uganda, Zimbabwe, and Kenya. In Queensland (Australia), which is one part of formal Gondwana land, tomato is infected by fruit fly *Bactrocera tryoni* (Balagawi *et al.*, 2005). In this study, the pest expands their range through distribution (movement of individuals), human transportation of contaminated fruit and expansion of tomato farming. These also contribute in increasing the home range of *D. punctatifrons*. But that distribution seems to be limited only in the tropical forest. Many field studies reported that the limits of the distribution of a species may be set by geological barriers that have not been crossed, or by ecological conditions to which the species is not adapted (Futuyma, 2005). *D. punctatifrons* is very sensitive to temperature, in our study areas when the temperature was more than 25°C they were rarely found on the field and this could be the main barrier to the expansion of this pest. Also *H. armigera* and *D. punctatifrons* larvae have clumped distribution within tomato gardens, with individuals group together on the fruits. Russell *et al.* (2008) explained why clumped distribution is extremely common in nature by the fact that suitable conditions often have a patchy distribution and also, organisms are clumped because of their reproductive patterns. Other insects that feed on tomato like *Chrysodeixis chalcites, Spodoptera litoralis* and *Neosilba* sp. were not considered as pests because their rates of attacks were inferiors to 3%. Since the works of Navarajan (2007), an insect that feeds on a plant is consider as pest only when it causes a yield losses higher than 10 %.

The local variety of the tomato "Cherry tomato", is less likely with the attacks of the insects than the improved variety or exotics. This could be explained by the fact that, the local variety has fruits of very small sizes which offer less food resources to the pest as compared to the exotic or improved variety "Rio Grande", which is very fleshy with a great quantity of resources. Another explanation can that the local varieties would have developed mechanisms of resistance following the long period of contact with their pests. Erbout (2010) explain that the plant hosts are also able to react to the attacks of the pest by producing some pheromones that can attract or repel the pests.

The results also revealed that, the yield losses vary significantly according to the varieties. These losses are mainly the fact of two insects which acquired the status of pests. Based on the result of Navarajan (2007), only *D. punctatifrons* and *H. armigera* are considered as pests. Other insects like *C. chalcites*, *S. litorallis, Neosilba* sp are regarded as the secondary pests who feed on tomato without however inflicting prejudicial damage on it (Navarajan, 2007). The harmful effect of *Neosilba* sp. Was more important on some plant of the Solanaceae familly like tomato (Elono-Azang *et al.* 2016).

The results also showed that *D. punctatifrons* and *H. armigera* respond to the clumped distribution on tomato fruits by separating their period of food exploitation within time. This separation of warm period can originate from: a long co-evolutionary process that occurs in past competition within the pests; these pests certainly have another food resources on which they feed at a particular time. Barbault (1997) indicated that host diversification can contribute to the reduction of competition in phytophagous insect. Bruno *et al.* (2005) recorded around 120 studies of species interactions during invasions. These authors also concluded that although interspecific competition is frequent in this context, it does not often result in competitive exclusion of resident species. However the competition between the two species can only partially explains the temporal distribution.

The separation can also originate from climatic factors which constitute an important part in these overlapping populations. Because these always occur in the transitional period between rainy and dry season that is mid-November. This overlapping of populations was observed twice in the year during the same seasons and the cycle recommence the next year. Duyck *et al.* (2008) pointed out climatic factors to be responsible for the overlapping of fruit feeding insect in La Réunoin. Another effect of competition were the fact that *D. punctatifrons* laid their eggs during the day time within early green tomato fruits, while *H. armigera* laid theirs at night on the leaves and the stems of the tomato. These antipathy behaviors might have been the keys of the cohabitation of these pests on tomatoes.

Conclusion

D. punctatifrons and *H. armigera* are polyphagous pests; their impact varies significantly with their hosts. Both interspecific competition and climatic factors may be responsible for separation in time of fruit exploitation periods of these two pests. *H. armigera* caterpillar may become more and more dangerous in the next few years as they continue to increase their host ranges. The long term competition between two species can lead to evolutionary divergence of their host. Knowledge of the behaviour of these pests is an important passage in an integrated approach for the protection of tomato. The control of these pests would effectively be successful with the mastering of their ecology and the identification of their natural enemies.

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