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Bioecology of the fruit fly *Dacus punctatifrons* on tomato and host range expansion

(Bioekologi lalat buah *Dacus punctatifrons* pada tomato dan pengembangan perumah)

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Key words: Cameroon, *Dacus punctatifrons*, biology, tomato, field infestations, over seasoning hosts

Abstract

Investigations on the oviposition/oviposition behaviour, developmental studies and general ecology of *Dacus punctatifrons* were conducted in the laboratory and tomato fields in Buea, Cameroon. This study revealed that *D. punctatifrons* has clearly expanded its host range to tomatoes (*Lycopersicon esculentum* Mill) in Cameroon. The female flies oviposit into unripe tomato fruits to deposit a cluster of 3–10 eggs, which hatch 1–3 days later. The larvae feed on the fruit pulp until about pupation, then drop either singly or together with the enclosing damaged fruit from which they emerge, wriggle and burrow 2–5 cm below the soil surface to pupate. Pupal and total developmental periods were about 12 and 25 days, respectively. Mean adult longevities were 11.75 and 16.85 days for males and females, respectively. A range of 1–3 oviposition punctures and 1–12 larvae were found per fruit.

Generally, the percentage of infested plants per field varied with location but was often <40% within 1–3 weeks after fruiting, irrespective of site; this eventually increased beyond 80% in most fields. The percentage of infested fruit also varied with location but was often <20% from 1–7 weeks after fruiting before drastically increasing to around 60% beyond week 7 regardless of site. The major natural enemies of the flies observed in this study were various ants and bird species. These results are discussed in the light of possible options for cost-effective, environmentally friendly and sustainable management strategies for *D. punctatifrons* that currently inflicts heavy damages on tomatoes in Cameroon.

Introduction

Dacus (*Dacus*) *punctatifrons* Karsch (Diptera: Tephritidae) is a fruit fly belonging to the subfamily Dacinae. Most pest species of Tephritidae attack many major commercial fruits and the great majority belong to the genera Anastrepha, Ceratitis, Bactrocera, Dacus and Rhagoletis (Hooper 1988; Hancock 1989; White and Elson-Harris 1992). These genera are characteristically poplyphagous and multivoltine, having adults that are very mobile with high potential fecundity and ability to survive adverse conditions. The

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larvae of most fruit fly species develop in the seed-bearing organs of plants; about 35% of species attack soft fruits including many cultivated fruits (White and Elson-Harris 1992).

Although members of the genus *Dacus* have been mentioned as the most economically important fruit flies because they cause severe damage to fruits and vegetables (Agarwal 1988), 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. The adult of *D. punctatifrons* is an orange-brown fly with a medial black stripe on the scutum (Carrol et al. 2002). The female adult has a long extensible ovipositor, which is characteristic of the female Tephritidae. These females use the ovipositor to insert their eggs within the intact unripe tomato fruits.

Dacus species are distributed throughout the tropical and sub-tropical regions of the world and appear to be endemic to the tropical and sub-tropical rain forest (Drew 1989). In addition, White and Elson-Harris (1992) reported *Dacus* as an Afrotropical genus although a few species are also paleotropical and subtropical. *Dacus punctatifrons* and *D. ciliatus* Loew have been reported mainly on cucurbits host plants in Cameroon (Munro 1984; Hancock 1989) while *Dacus bivittatus*, *Ceratitis rosa* and *Ceratitis pedestris* are known as occasional pests of tomatoes (*Lycopersicon esculentum* Mill) (Hancock 1989).

However, recently, *D. punctatifrons* has become a prominent pest on tomatoes in the Centre and Southern Provinces of Cameroon where at times some farmers abandoned entire tomato fields due to heavy infestations by the fruit fly (Tindo and Tamó 1999). This fly has obviously expanded its host range in Cameroon to include tomatoes. Given the high mobility and search ability of fruit flies and their ability to easily invade new agricultural areas, it is likely that these flies will soon over run the tomato producing belt of Cameroon and beyond if this is not the current situation. Considering that tomato serves as a cash and food crop in Cameroon, there is increased concern about the rising fruit fly infestations and thus the need to check their spread.

Our hypothesis was that *L. esculentum* fruits are suitable food substrates for post-ovipositional development of *D. punctatifrons*. To test this hypothesis and also generate a database required to initiate a sustainable and environmentally friendly management strategy for these flies, we studied aspects of the biology and ecology of the fly. Therefore, the objective of this work was to study the biology of *D. punctatifrons* infesting tomato in Buea; determine its incidence and damage severity on tomatoes in this area as well as its means of over seasoning. The aim was to highlight possible options available for suppressing the pest population.

Materials and methods

The studies were carried out from October 1998 to May 2001 in Buea, a town in Southwest Cameroon at 247.89°N and 58.24°E and an altitude of 530 m above sea level. Buea is on the east slope of Mount Cameroon, 30 km from the Atlantic Ocean, temperature range of 18–23 °C and an annual rainfall of about 4,090 mm. It has an equatorial climate with a rainy season running from May to October and a dry season from November to April. Tomato is cultivated mainly during the dry season by farmers and many market gardeners.

Adult *D. punctatifrons* specimens were collected from tomato fields and sent to the International Institute of Tropical Agriculture, Cotonou, Benin Republic for identification and where voucher specimens are lodged. The developmental studies were conducted in the laboratories of the Department of Life Sciences, University of Buea while the field studies were carried out in farmers' fields in the major residential areas of Buea viz.: Molyko, Bonduma, Great Soppo, Clerks Quarters, Small Soppo, Bokwoango and Buea Town. Fields used in the study had at least 80 tomato plants of the most widely cultivated variety in the Buea area, which is an indeterminate variety with large red coloured fruit. Most of these fields also had other vegetable crops like lettuce and cabbages.

Oviposition and larval developmental studies

A total of 20 fruiting tomato plants were randomly selected from each field and the plants tagged with a piece of red cloth tied around the stems. Every fruit on each tagged plant was observed daily for oviposition spots. Fruits with oviposition spots were harvested, taken to the laboratory and the area containing the eggs excavated and placed on paper towel in a petri dish and covered to prevent the eggs from drying off. The petri dish was then placed in the laboratory at 20 ± 2 °C and relative humidity of 75 ± 10%, and the eggs were observed daily to record the date of eclosion in order to determine the incubation period. A total of 20 egg batches of 3–10 eggs each were observed although the mean incubation period was calculated from 20 eclosed eggs.

First instars (maggots) that hatched from the eggs above were transferred individually to a tomato fruit placed in petri dishes lined with filter papers to absorb the juice from the fruits because the larvae usually drown in excessive liquid. The tomato fruits were replaced on alternate days but the larvae were observed daily for pupation. The interval between the dates of eclosion and pupation gave the larval duration; there were 20 replicates. The ensued pupae were weighed one day after pupation using a *Mettler* balance (sensitivity 1 mg). Each pupa was then placed in a petri dish and kept in the laboratory under ambient conditions and observed daily until adult emergence to obtain the pupal duration. Emerged adults were sexed and weighed on the same day of emergence. This was done by first weighing a small cuboid with a tight fitting lid before an adult was then placed in the container and re-weighed. The difference between the weight of the container with the fly and that without it gave the weight of the fly.

Adults that emerged on the same date were released in plastic mesh wooden cages supplied with paper towel wicks soaked in different solutions (tomato juice, 4% sugar solution and 4% honey solution) as food sources for the adult flies. The legs of the cages were placed in small plastic tins containing kerosene to prevent ants entering the cages. The wicks and various solutions were changed twice per week while the flies were observed daily to record mortalities and sexes of the death insects. The time interval between the date of emergence and death gave the adult life span.

Tomato plant and fruit infestation studies

Six fields with the same tomato variety and each having at least 80 plants were selected from different residential areas of Buea. The various farm owners were allowed to carry out all normal tomato cultivation practices in the Buea area such as the application of fungicides and insecticides like *Ridomil* (600 g/kg copper hydroxide, 30 g/kg metalaxyl-M) and *Sevin* (carbaryl). Each field was examined once weekly from 0600–1800 h to determine when the adult fly visited the plants. At flowering, 20 plants were randomly selected from each field and tagged for subsequent sampling.

On each sampling date, the percentages of infested plants and fruit were recorded separately. A plant was considered infested if at least one of its fruits had a fruit fly oviposition spot. At the end of the experiment, weekly percentage infestation of plants and fruit in each field were then calculated as follows:

Percentage of infested plants = [Number of infested plants out of 20/20] x 100

Percentage of infested fruits = [Number of infested fruits on the 20 plants/Total number of fruits on the 20 plants] x 100

Separate cumulative percentages of infested plants and fruit for each site were then calculated.

Natural enemies and over seasoning host studies

A total of 30 fruits, each containing oviposition spots, were collected from various tomato fields. These were placed in transparent plastic containers padded with paper towels and covered with lids, then kept at ambient conditions in the laboratory and observed daily for the emergence of natural enemies. In another observation, dropped infested fruits were observed in-situ daily in the fields to identify the arthropods and vertebrates that consumed them. Similarly, during the tomato off-season, selected infested fields were visited once monthly. On each visit, leftover fruits and those that fruited subsequently after the harvest were inspected for oviposition spots and/or presence of larvae. Surrounding plants 1–5 m on each side of the fields were also observed from 0700–0900 h for the presence of adult fruit flies. Similarly, fruits of *Psidium guajava*, *Mangifera indica*, *Carica papaya* and *Cucurmis mela* around the infested fields were also observed once monthly for *D. punctatifrons* oviposition puncture and/or damage.

Results

Oviposition behaviour and pattern

The characteristic sign of *D. punctatifrons* infestation on tomatoes is a tiny brownish or darkish oviposition spot on the tomato fruit especially on the unripe fruit. The females usually laid their eggs between 1000–1100 and 1400–1500 h. Prior to laying, the female alights on an unripe fruit and moves around a particular spot or section of the fruit. It then extends its ovipositor and forces it into the fruit by bending its abdomen and thorax such that the entire body becomes somewhat curved. After this, it relaxes and walks around the spot for about 1–2 min and the cycle of activities resumes: this can be done about 4–5 times on that same spot. After the last episode of forcing its ovipositor into the site, it stays stationary for about 3–5 min, and then it moves around the site again before leaving the fruit. The entire oviposition period varied from 10–25 min. A maximum of 3 oviposition spots was observed per fruit. The number of eggs produced per female in a single oviposition spot ranged from 3–10; these eggs were often in clusters.

Post-ovipositional development

The mean egg incubation period was 1.55 ± 0.135 and 1.65 ± 0.39 days for males and females respectively, with a range of 1–2 days *(Table 1)*. Larvae that hatch from these eggs are whitish in colour but gradually turn yellowish prior to pupation. The larvae can wriggle and jump over a few centimetres. They feed on the tomato pulp to develop thus completely damaging the fruit and rendering it unfit for human consumption. Usually the unripe fruit also ripens and/or rots prematurely and eventually drops. The larvae leave the fallen fruits and wriggle away and/or dig into the soil or litter to about 2–5 cm below the surface to pupate.

There were no significant differences in the total developmental periods between male and female flies (25.95 and 25.65 days for males and females respectively). However, the pupae that developed to female adult flies weighed significantly more ($p \leq 0.05$; t-test) than their male counterparts ($t = 7.183$, $df = 38$, $p = 0.005$). Similarly, female adult flies weighed more than the males *(Table 1)*.

Field infestations

Adult *D. punctatifrons* were not generally found on the tomato plants before sunrise. Often, the flies were found on plants surrounding the fields such as *Tethonia* spp. on which they roost in the early mornings prior to moving into the tomato fields for oviposition and/or feeding.

The percentage of infested plants varied from one site to another and with the

Table 1. Mean developmental duration (days ± S.E), pupal and adult weights (mg ± S.E) of *Dacus punctatifrons* on tomato fruit

	Male (n = 20)	Female (n = 20)
Incubation period	1.55 ± 0.135a (1–3)	1.65 ± 0.39a (1–3)
Larval duration	12.45 ± 0.164a (9–15)	12.00 ± 0.356a (9–15)
Pupal duration	11.95 ± 0.246a (11–14)	12.00 ± 0.229a (11–14)
Total developmental period (egg-adult)	25.59a	25.55a
Pupal weight	11.78 ± 0.35a (9–14)	16.80 ± 0.58b (13–22)
Adult weight	11.15 ± 0.29a (9–13.5)	14.65 ± 0.49b (11–18.5)
Adult life span	11.75 ± 1.28a (6–15)	16.85 ± 1.63b (8–33)

Means followed by the same letter in a row are not significantly different (p >0.05, Student t-test)

Table 2. Tomato plant population per field at various elevations and percentage of plants infested at 50% fruiting and fruit ripening

	Molyko	Bonduma	Great Soppo	Small Soppo	Clerks Quarters	Bokwango	Buea Town
Altitude (m)	637.5	685	700	846	840	948	956
Crop population	80	>200	93	85	>200	>200	103
Infestation at 50% fruiting	0	35	18	5	22	43	0
Infestation at 50% fruit ripening	35	90	25	15	90	85	50

tomato crop phenology *(Table 2)*. At Bonduma and Bokwango, early infestation was below 40% but this increased to above 90% at 10 weeks after fruiting (WAF). At Clerks Quarters, infestation remained below 40% until 7 WAF but increased rapidly to above 90% at 10 WAF. At Molyko and Buea Town, infestation was noticed only at 9 WAF and thereafter it rose to over 40% within 2 weeks. At Small Soppo and Great Soppo, percentage of plant infestation remained below 30% throughout the study period *(Figure 1)*.

Usually at the onset of the tomato fruiting period, a few fruits had oviposition spots but as more fruits were produced, the proportion of infested fruits increased accordingly. Generally, for the first 7 WAF, fruit infestation levels ranged from 0% in Buea Town and Molyko to about 12% in Bokwango, rose to 70% at 10 WAF. At Small Soppo and Great Soppo, though with early infestation, the percentage of infested fruit was less than 10% throughout the study period. At Buea Town and Molyko, fruit infestation was only noticed at 9 WAF *(Figure 2)*.

Natural enemies and over seasoning hosts

No parasitoids emerged from any of the larvae and pupae collected from the field and reared in the laboratory. However, most of the fallen infested fruits in the fields were consumed by various species of birds. Similarly, various species of ants also fed on larvae and pupae in fallen fruits even in the

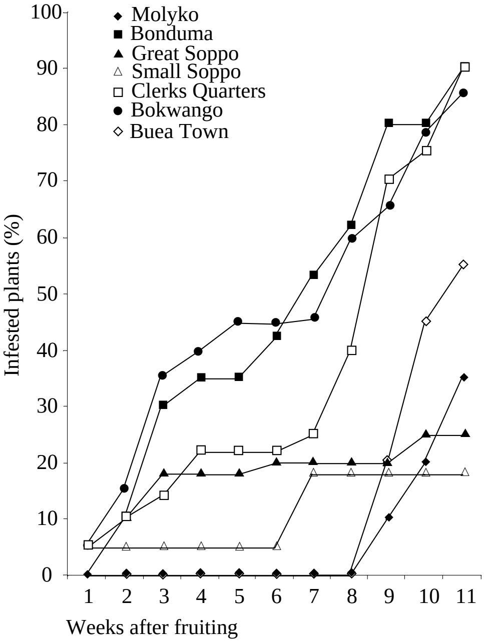

Figure 1. Percentage of ***Dacus punctatitrons*** *infested plants in various tomato fields in Buea Town during the 1997–98 season*

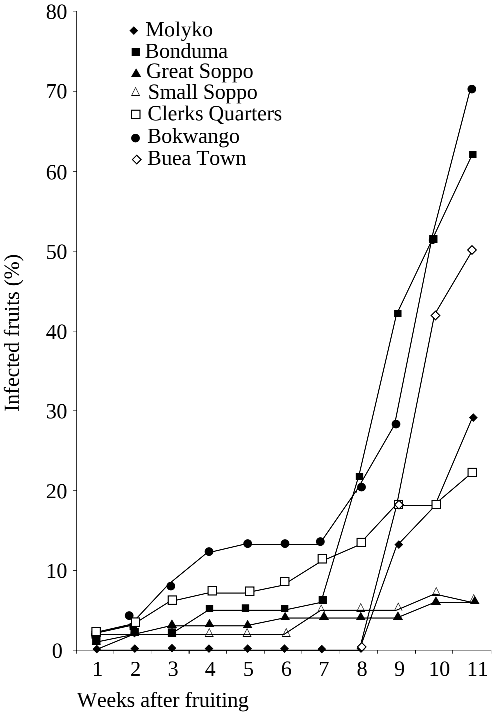

Figure 2. Percentage of ***Dacus punctatifrons*** *infested fruits in various tomato fields in Buea Town during the 1997–98 season*

laboratory whenever these were not protected from ants. During the tomato off-season, the flies continue to feed and oviposit on the leftover fruits and those that fruited subsequently after the marketable ones had been harvested.

Dacus punctatifrons also infests *C. mela* fruits *(Table 3)*. They lay their eggs in the young green fruits and the resultant larvae feed on the fleshy tissue of the fruit.

Discussion

The total developmental period of the fly was about 25 days for both sexes implying that its life cycle suits the fruiting period of tomato, which is usually around 1 month. Consequently, larvae usually complete their development concealed in the fruits. Therefore attempting to control these destructive larvae with the usually applied contact insecticides is not appropriate, since the chemicals do not come in contact with the larvae. Systemic insecticides could be a more promising alternative but their residues may not be totally degraded before the fruits are marketable thus posing potential toxic hazards to humans.

Consequently, it is preferable to either target the adults for insecticide application or formulate alternative control strategies such as the use of oviposition deterrents that prevent the adults from ovipositing on the fruits or the use of bait traps. However, Hooper (1988) emphasized the importance of cover and bait sprays for controlling fruit flies while Allwood et al. (2005) report on the eradication of *Bactrocera* species in Nauru using protein bait application techniques (BAT). Cover spraying involves use of systemic insecticides such as dimethoate (Rigor) to kill immature stages present in fruits while BAT is the mixing of protein sources of adults with odourless chemicals such as Fipronil to kill young females before they reach the egg-laying stage.

Furthermore, since the insect usually pupates in the soil when the damaged infested fruits drop, frequent collections of

Table 3. Food host plants of *Dacus punctatifrons* at different periods of the year in the Buea area

Plant species	Family	Jan.	Feb.	Mar.	Apr.	May	June	July	Augt.	Sept.	Oct.	Nov.	Dec.
Persea americana	Lauraceae	–	–	–	–	–	–	–	–	–	–	–	–
Psidium guajava	Myrtaceae	–	–	–	–	–	–	–	–	–	–	–	–
Lancium esculentum	Solanaceae	+	+	+	+	–	–	–	–	–	+	+	+
Carica papaya	Caricaceae	–	–	–	–	–	–	–	–	–	–	–	–
Cucumis melo	Cucurbitaceae	–	–	–	–	+	+	+	+	+	+	–	–

– = Not infested; + = Infested

fallen fruits from the field will greatly reduce the pest population. Staking of the tomato plants is advisable in order to raise the fruit above the ground to facilitate the spotting of dropped fruit for collection.

The pupal and adult weights of female *D. punctatifrons* were significantly higher than the male. This is consistent with the studies of Keiser (1989), who reported that adult females of oriental, melon and Mediterranean fruit flies weighed significantly more than the males. The higher average weights of females suggest that the female larvae possibly consumed extra food. Similarly, females lived longer than the males most probably because of the accumulation of more nutrients for egg maturation and for sustaining basic metabolic activities. Females of *Ragoletis cingulata* have been found to feed more often than the males (Smith 1984). Liquido and Nakagawa (1991) also established that the females of *D. dorsalis* Hendel lived longer than the males in most study sites under natural conditions.

The higher levels of infested plants and fruits in Bonduma, Clerks Quarters, Bokwango and to an extend Buea Town appeared to correspond with the higher tomato plant population per field in these sites *(Table 2)*. This is understandable since higher plant abundance implies the availability of more fruits and thus attracting more fruit flies. Rejesus et al. (1991) established that populations of *Dacus* spp. and *Monoscrostichus* spp. were positively correlated with fruit abundance.

There was a steady increase in infestation of plants and fruit over time. This was possibly because infested fruits that dropped were left in the fields to enable the larval and pupal stages complete their developments with little interruption, giving rise to adults that adequately fed on the decaying fruits to subsequently produce more offspring. This suggests that harvesting and destroying or burying of the early-infested fruits in a field can significantly deplete the fly population later in the season since each fruit usually harbours many eggs.

Though the proportion of infested plants and fruits increased with time, the rate of increase was very low within the first 7 WAF but increased subsequently. The tomato cultivar grown in Buea is indeterminate and the first 7 WAF coincide with when fruits of high market value are produced. Management practices are also intensive during this period and could have helped to check the fly's population. The period of rapid increase in fly's population coincides with cleaning when the farms are less intensively managed. These poor management practices coupled with the already emerged adults from the early infestation may account for the rapid increase of fly during this period.

After harvesting of the marketable fruits, the farms are abandoned with most of the smaller and/or damaged fruits exploited by the flies for feeding, breeding and building up of higher populations. The tomato fruit leftovers in the fields enable the flies to have continuous cycles from one season to another. Therefore gathering up and destroying all crop residues from the previous season may also alleviate this fly problem. Currently, invertebrate natural enemies appear not to be a significant mortality factor for these flies on tomatoes in Cameroon. This may be because the first report on the association of these flies with tomatoes was in 1987 (Tindo and Tamó 1999); consequently, indigenous invertebrate natural enemies may not have adequately adapted to feed on these flies.

Currently, *L. esculentum* (Solanaceae) and *C. mela* (Cucrbitaceae) serve as food sources for *D. punctatifrons* in the Buea area. Given that the cropping season of *C. mela* and other curcubits grown in the area coincide with the tomato off-season, this crop and allied cucurbits may be the main host plants of the fly during the tomato off-season. This will probably enable the insect to have continuous cycles throughout the year without going into diapause.

In spite of the current high *D. punctatifrons* infestations on tomatoes in most areas of Cameroon, the current common practice of conventional insecticide application on the crop should be minimised. More attention should be paid to detailed studies of the pest ecology in order to formulate more sustainable and ecologically friendly management strategies. Cover and protein bait sprays could also be effective for *D. punctatifrons*. Staking of plants should be encouraged since this practice raises fruits above the ground to facilitate collection of dropped fruits from the soil surface to avoid a high population build up later in the season. Tomato crop residues after harvesting the marketable fruits should also be gathered and burnt to avoid a carry-over population of the fly. Detailed studies on the existence of local natural enemies of the fly and possibilities of using locally sourced, cheap and environmentally friendly botanicals to replace the more toxic and expensive imported synthetic insecticides in suppressing this pest population should be encouraged.

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Abstrak

Kajian tingkah laku pengoviposian/pengoviposian, pembangunan dan ekologi am *Dacus punctatifrons* telah dijalankan di dalam makmal dan ladang tomato di Buea, Cameroon. Kajian ini menunjukkan *D. punctatifrons* telah jelas mengembangkan bidang perumahnya ke tomato (*Lycopersicon esculentum* Mill) di Cameroon. Lalat betina oviposit ke dalam buah tomato yang belum masak untuk memasukkan sekelompok 3–10 biji telur, yang menetas 1–3 hari kemudian. Larva memakan pulpa buah sehinggalah pempupaan, kemudiannya jatuh sama ada satu per satu atau bersama-sama dengan buah rosak dari mana mereka muncul, dan mengorek 2–5 cm di bawah permukaan tanah untuk mempupa. Tempoh pembangunan pupa dan jumlah tempoh pembangunan masing-masing ialah 12 dan 25 hari. Purata kelanjutan usia dewasa jantan dan betina masing-masing ialah 11.75 dan 16.85 hari. Sebanyak 1–3 lubang pengoviposian dan 1–12 larva telah ditemui pada setiap buah.

Umumnya, peratus tumbuhan yang diserang bagi setiap ladang adalah berbeza-beza mengikut lokasi tetapi sering <40% dalam tempoh 1–3 minggu selepas berbuah, tanpa mengambil kira kawasan; ini akhirnya meningkat melebihi 80% dalam kebanyakan ladang. Peratus buah yang diserang adalah berbeza-beza mengikut lokasi tetapi merupakan sering <20% daripada 1–7 minggu selepas berbuah, sebelum meningkat secara drastik kepada kira-kira 60% selepas minggu ketujuh tanpa mengira kawasan. Musuh semula jadi utama lalat buah dalam kajian ini ialah pelbagai spesies semut dan burung. Keputusan ini dibincangkan untuk mendapatkan pilihan strategi pengurusan yang kos efektif, mesra alam dan mapan untuk *D. punctatifrons* yang pada masa ini menyebabkan kerosakan yang teruk pada tomato di Cameroon.

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