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Dynamics of the flea beetle *Podagrica decolorata* Duvivier, 1892 (Insecta: Chrysomelidae) on okra crops: implications for conservation of the Tanoe-Ehy Swamp Forests (south-eastern Ivory Coast)

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1 SUMMARY

The study was on the dynamics of the flea beetle on okra crops and implications on conservation of the Tanoé-Ehy Swamp Forests in south-eastern of Ivory Coast. The biological material of the study consisted of okra seeds, which were sown in a complete randomized system. The data collection focused on the number of insects (*Podagrica decolorata*) in okra fields during the rainy season and dry seasons. Twenty five (25) to 45 adults and larvae were recorded per plant during the dry season whereas 5 to 10 insect individuals were collected in the rainy season. Okra yields varied from 30 to 40 t ha $^{-1}$ in the rainy season against 15 to 20 t ha $^{-1}$ in the dry season. This was correlated with indices of insect damage in dry season, which were more than 50% of destroyed leaves. During the rainy season, less than 25% of leaves damaged. These results showed that areas adjacent to the Tanoé-Ehy Swamp Forests could be used in a context of the forest remnant conservation for cultivating vegetables and hence generate incomes to local populations.

2 INTRODUCTION

Abelmoschus esculentus (L.) is commonly known under the name of okra, and is an important vegetable crop valued for its edible green seedpods, leaves and immature fruits (Okigbo, 1990; Khomsug *et al.*, 2010; Marwat *et al.*, 2011). In most sub-Saharan Africa countries, this vegetable provides mucilaginous consistency after cooking and is consumed as soups, stews or sauces. Besides the nutritional benefit, seeds, infusion of the fruit mucilage, decoction of the immature fruit, leaves and flowers, extract of leaves or juice and infusion of the roots have pharmacological properties. They are used extensively in traditional medicine such as diabetes mellitus therapy, treatments of bronchitis and pneumonia, remedies for tumour or treatment of spermatorrhoea and syphilis (Barrett, 1994; Babu and Srinivasan, 1995; Marwat *et al.*, 2011; Sabitha *et al.*, 2011; Roy *et al.* 2014). Unfortunately, the yields of okra crops in fields are still decreasing in several areas of Africa due to viral diseases. In Ivory Coast particularly, so far the flea beetle *Podagrica decolorata* Duvivier, 1892 is the main vector of the transmission of the Okra Mosaic Virus (OkMV) (Givor and den Boer, 1980; Ugwoke and Onyishi, 2009) (figure

1). Plants are stunted and damaged after inoculations when they are attacked by the insect pest. Moreover, Okra mosaic virus infection reduced fresh weight of okra fruit up to 42% depending on the cultivars (Marchie, 1993). *P. decolorata* is also responsible to up to 95% decline in cotton crop yields in some northern parts of the country (Hana *et al*., 2005, 2006). However, it is surprising that published information on the flea beetle is sparse. Little is known about its biology and ecology and comparative studies are lacking in south-eastern Ivory Coast. Hence, the paucity of information available on *P. decolorata* is steadily attracting attention of entomologists because this insect pest imposes significant production constraints, affecting both yield and quality, and is very difficult to control (Yéboué *et al.,* 2002; Fondio *et al.,* 2007; Soro *et al.,* 2008). Among the market crops cultivated in surrounding villages of the Tanoé-Ehy Swamp Forests, okra crops generate a significant source of incomes for local populations (Soro, pers. obs.). In the context of a long-term sustainable development, generating opportunities such as the development of vegetables and legumes to small scale farmers to produce excellent incomes in these villages are needed and encouraged. In order to improve these activities and limit damages, the population dynamics of *P. decolorata* on okra yields need to be controlled. Tanoé-Ehy Swamp Forests has been recently designated as a "Very High" priority area for primates by researchers of the RASAP-CI (Research and Action Program for the Conservation of Primates in Côte d'Ivoire). This forest, which harbours several endemic and threatened species, is of high value for its conservation (Zadou *et al*., 2011; Kpan *et al*., 2014). To further enhance protection it has been recommended to collect and update the scientific information for this forest area and its surroundings (Koné *et al*., 2008). We therefore participated in a survey of neighbouring villages of Tanoé-Ehy Swamp Forests organized by the "Centre Suisse de Recherche Scientifique." We herein aim to 1) provide an assessment of the yield of okra crops in these villages, and 2) add information on the ecology of *P. decolorata*.


Figure 1: *Podagrica decolorata* on Okra fruit

3 MATERIEL AND METHODS

3.1 Study area: The survey was carried out from February 2013 to October 2014 in Dohouan, Kotouagnan, Nouamou and Saykro villages, all situated in the northern part of The Tanoé-Ehy Swamp Forests (5°05'–5°15' N; 2°45'–2°53' W), and covered the dry and rainy seasons (Figure 2). The Tanoé-Ehy Swamp Forests constitute 12,000 ha of remaining rainforest in the department of Tiapoum, south-eastern Ivory Coast. The mean annual temperature is 26°C; the mean annual precipitation is about 2000 mm. The long dry season lasts from December to March, and is followed by the period with highest precipitation from March to July. A short rainy season extends from October to November (Eldin, 1971). The Tanoé River crosses the southern and eastern parts of the Tanoé-Ehy Swamp Forests whereas the western part of this forest ecosystem is marked by the Ehy lagoon. The study area mainly consists of moist, partly primary forests on predominantly sandy soil with vegetation typical for south-eastern Ivory Coast (Béligné, 1994). Biological studies revealed a high richness of flora and fauna with many endemic species (Adou, 2007). This forest is facing human pressure due to agriculture, hunting and cutting firewood and lumber (ANCI, 1965a; 1965b; 1996).

Figure 2: The geographic position of the study area in the northern part of the Tanoé-Ehy Swamp Forests (modified from the Research and Action Program for the Conservation of Primates – Côte d'Ivoire 2010, unpubl. data).

3.2 Field experiments, row planting and weeding: Forty fields were visited in the four villages, 10 visits for each village. In each field, seeds of okra were sown in four randomized plots with four replications in the row planting method. Each plot covered a surface of 12 m² (4 m length x 3 m width) separated by parallel lines. The inter-plot distance was 1 m. distances for sowing between parallel lines and along lines were 30 cm and 100 cm respectively. Hoeing to remove weed infestation and to make the soil more friable was applied for the entire survey. During the dry season, seedlings and mature plants were watered regularly (morning and evening) in order to reduce and limit evaporation. In the rainy season while it seemed not necessary to water plants due to the weather condition, plants were however watered only in the morning in case rainfalls were irregular for intervals of three days. During the entire survey phytosanitary, treatments were not applied to avoid to compromise interactions between *P. decolorata* and okra plants.

3.3 Sampling methods: Adults of *P. decolorata* were sampled using traps. Each trap was consisted of a yellow plastic plate in which an aqueous solution of soap was deposited. The trapping system was positioned in a small excavation of the floor. Hence, adult insects attracted by the yellow colour of the plates were trapped when they fell into the aqueous solution of soap. For each plot, floating insects were recorded on the surface of the aqueous solution of soap (Collingwood et al., Soro, 2009) and thereafter preserved in 70% ethanol for biological survey. Each plot was visited once a week and insects were searched in the morning for two hours (07:00–09:00 GMT). To supplement opportunistic collecting, flying insects within plots were also sampled using dip nets. In addition to the adult insects, we investigated larvae as well. Insect larvae were collected each 10 days. For each plot, insects were searched and collected walking along the two central lines between okra plants.

3.4 Assessment method of damages of P. decolorata in okra fields: Insects attacked okra plants foraging leaves and fruits. For each plot, all the affected plants were counted. The index of severity was calculated in order to estimate the severity of the damages on plants Soro (2009). The scale of index is as follows: 1 = 0 to 25% destroyed; 2 = 25 to 50% destroyed; 3 = 50 to 75% destroyed; 4 = 75 to 100% destroyed. The damage was high when the index of severity reaches 3. Hence, more than 50% of the parts of the plant were considered as destroyed. Okra yields were estimated in ton per hectare at the end of the survey. The yield calculation is as follow: R = M/S; (R = yield per t per ha; M = weight, in tones; S = surface, per ha.). Statistical analyses were performed with the linear model of the SAS system version 8.2.

4 RESULTS

4.1 Dynamic of adults and larvae: During the dry and rainy seasons, there was a difference between larvae and adults evolution within plots. The number of larvae was more important than the adults. For each developmental stage, recorded larvae were more abundant during the dry season than the rainy season (Figure 3). Likewise, adults of *P. decolorata* were more abundant during the dry season than the rainy season. In a same season, the number of recorded larvae was similar in all villages. However, during the rainy season the number of larvae was more abundant in the villages of Nouamou and Dohouan than Kotouagnan and Saykro. In the same way if the evolution of larvae and adults were similarly during the dry season, the same evolution was not observed in the rainy season when the number of larvae and adults were considered. It is appeared that the number of larvae and adults do not always move in the same direction. In fact, in Kotouagnan, during the rainy season the number of larvae is less important than the number of adults (Figure 3).

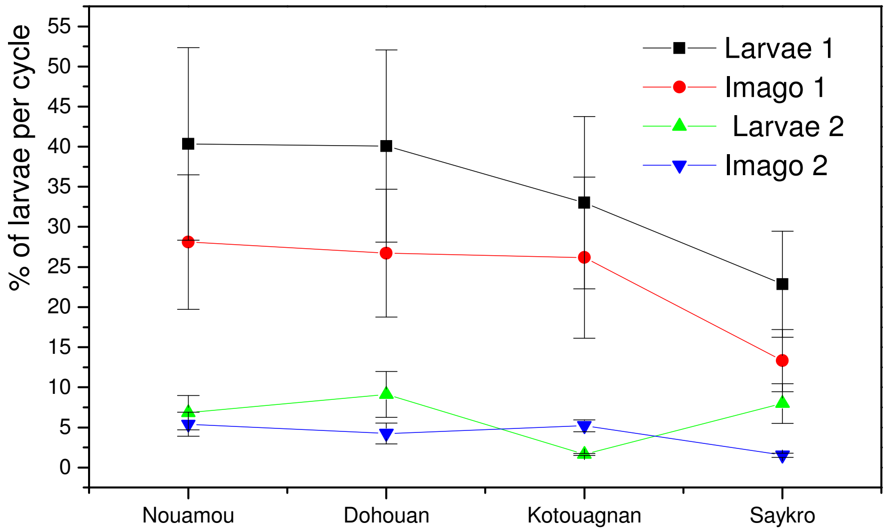

Figure 3: Population dynamics of *P. decolorata* in plots within Nouamou, Dohouan, Kotouagnan and Saykro villages. Larvae 1= larvae collected in dry season; larvae 2= larvae collected in rainy season; Imago 1= adults collected in dry season; Imago 2= adults collected in rainy season.

4.2 Damages on plants: The damage estimated on plants was more important during the dry season than the rainy season. In the dry season, at Nouamou and Dohouan, the means of the index of severity were lower than 3 (Table 1). In both villages, the rate of the damage was low. However, at Kotouagnan and Saykro, the index of severity was higher than 3. On these sites, the rate of described damages was the most severe. During the rainy season, the rate of attacks in all the sites was very low (less than 2). On the sites of Nouamou and Dohouan, the rate of attacks seems more important than Kotouagnan and Saykro (less than 1). The data collected on the sites of Nouamou and Dohouan seemed more homogeneous than those collected in Kotouagnan and Saykro. These were observed by the standard deviations, which were more homogeneous for Nouamou and Dohouan than the other villages (Table 1).

Table 1: Index of Severity estimated on plants with respect to seasons and villages

Villages	Dry season severity	Rainy season severity
Nouamou	2.14 (± 0.92)	1.5 (± 0.71)
Dohouan	2.85 (± 0.92)	1.3 (± 0.70)
Kotouagnan	3.74 (± 0.09)	0.13 (± 0.09)
Saykro	3.49 (± 0.92)	0.26 (± 0.90)

4.3 Estimated yield: Two groups of yields are observed during the dry and rainy seasons (Figure 4). For each village, the yields observed in dry season were lower than these obtained in rainy season (plot above). However, when the yields were taken individually, the better yields seemed to be obtained in Nouamou during the dry and rainy seasons. In the rainy season, the low yield was obtained in Saykro compared to the other villages. Nevertheless, in the dry season, the lowest yield was registered in the Kotouagnan village. While yields grew up from 25 to 40 t ha^{-1} in Saykro and Nouamou during the rainy season, it varied from 12.5 to 22.5 t ha^{-1} in Kotouagnan and Nouamou in the dry season.

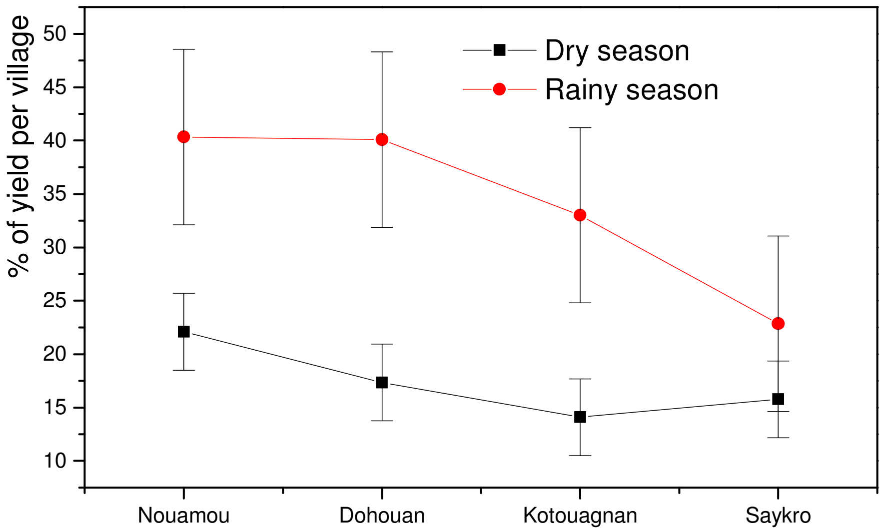

Figure 4: estimated yields with respect to villages during the dry and rainy seasons

4.4 Model effect compared to collected data: The model effect between seasons for larvae was significant statistically ($R^2 = 0.87$; Table 2). Likewise, comparisons of adults' effect were significant too. However, the interaction between larvae and adults were not significant (F-test, p <0.4692). With respect to seasons, the larvae effect was significant during the dry season ($R^2 = 0.61$) whereas the adult effect was not significant in the same. In the rainy season, the larvae and adults effects were significant statistically ($p < 0.0001$) (Table 2).

Tableau 2: Model effect on *P. decolorata* dynamic with respect to seasons

General model	R^2= 0.87; F-test, p < 0.0001
Larvae	0.0001
Adults	0.0001
Larvae*Adults	0.4692
zone (season)	0.0016
Dry season	R^2= 0.61; F-test, p < 0.0001
Larvae	0.0219
Adults	0.2031
Rainy season	R^2=0.77; F-test, p < 0.0001
Larvae	0.0061
Adults	0.0018

4 DISCUSSION

The effects of *Podagrica decolorata* populations on okra fields in the surrounding villages of the Tanoé-Ehy Swamps Forests were studied. The statistical significance of the general model in dry and rainy seasons may explain the independence of larvae and adults of *P. decolorata* during the okra production (Gnago *et al.*, 2010). However, given the fact that the estimated effects (larvae * adults) were not significant statistically (F-test, p = 0.4692), there was no correlation between the number of larvae and adults in each season (Fauquet, 1987). These results indicate that, in the same season, selecting pressure did not have effects on the development of larvae and the adults. According to Glitho (2008), the different phases of insect development did not show the same selecting pressures during seasons. This supposes that the observed number of larvae and adult in each season is normal. The different phases of *P. decolorata* move in the right way. It is likely that insect phases were neither influenced by the conditions of the study nor by external factors as it is illustrated by Givord and den Boer (1980). The abundant of seasonal yield of okra varied with respect to abundances of larvae and adults on plants (Sall *et al.,* 2002). Externals factors may play a minor role in insect developmental phases during field work. During the dry season, for each village, the number of larvae of *P. decolorata* had significant effects on okra whereas no significant effects were observed on the abundance of adults. During the rainy season, there was a significant effect on the number of larvae and adults. This could be explained by the fact that insects are much more active and mostly reproduce in the rainy season. The majority of insects feed and grow on spontaneous weeds and move thereafter on cultivated plants in the wet season. The situation differs in the dry season, which constitutes an unfavourable condition for insects breeding and propagation. Indeed, Givord and den Boer (1980) showed that the larvae of *P. decolorata*, which are soil-born insects, develop only in the dry season. However, Soro *et al*., (2010) and Yéboué (2014) have reported that number of recorded insects may increase during the dry season in some production cycles. The low yields obtained during the dry season could be attributed either to the high pressure of pests on fields or to the scarcity of rainfall during this season (Déclert, 1990; Kataria *et al*., 2014). The low yields could be because the farmers of Kotouagnan and Saykro villages did not receive appropriate trainings for okra cultivation. However, the yields obtained (10 t ha^{-1}) were higher than those estimated by Fondio *et al*. (2007).

5 CONCLUSION

While vegetables easily grow in the surroundings of the Tanoé-Ehy Swamps Forests (yield obtained varied from 15 to 40 t ha^{-1}) and generate incomes to farmers, training local populations with good methods for cultivating market crops seems an alternative that may contribute to the conservation of the forest remnant. Moreover, it is recommended an association of the yields of okra obtained in the two cycles of production with phytosanitary protection methods to increase vegetable crops. Systematic programs of insect pests monitoring in okra fields should be undertaken or a biological control techniques or low effect toxicity molecules should be applied to improve yields (Bodji, 2007; Youdeowei, 2004).

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