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ARTICLE DE RECHERCHE / RESEARCH ARTICLE — OPEN ACCESS

# *Tithonia diversifolia*: beneficial companion plant to control Yellow Aphids on sugarcane fields in Tanzania

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**Abstract –** To find sustainable ways to protect its sugarcane areas from the key pest *Sipha flava* (Hemiptera: Aphididae) in north Tanzania, the local company TPC Limited funded a 6 months project in coordination with the French Agricultural Research Centre for International Development (CIRAD) to assess different agroecological practices, such as the use of companion plants around sugarcane fields. In this study, the influence of the flowering species *Tithonia diversifolia* located at the field edges as a potential banker plant for conservation biological control of the yellow sugarcane aphid was evaluated. Predatory species were identified by direct capture and/or regular observations and the intensity of aphid damage was evaluated through number of colonies. Twenty-four aphid predator species were identified being hosted by *T. diversifolia*, and the vicinity of this plant reduced by 86% the number of *S. flava* colonies in the sugarcane edges. These species belonged mostly to family Coccinellidae (ladybugs), Syrphidae (hoverflies), Chrysopidae (green lacewings), Dolichopodidae (long legged flies). This is the first paper evaluating *T. diversifolia*'s potential as a banker plant in sugarcane crops for pest control.

**Keywords:** Sugarcane / biological control / banker plant / *Sipha flava* / *Tithonia diversifolia*

**Résumé –** Afin de trouver des moyens durables de protéger leurs parcelles de canne à sucre contre le ravageur *Sipha flava* (Hemiptera : Aphididae) dans le nord de la Tanzanie, la société locale TPC Limited a financé un projet de 6 mois en coordination avec le Centre de coopération internationale en recherche agronomique pour le développement (CIRAD) pour évaluer différentes pratiques agroécologiques, telles que l'utilisation de plantes compagnes autour des champs de canne à sucre. Dans cette étude, l'influence de l'espèce à fleurs *Tithonia diversifolia*, située en bordure de champ, en tant que potentielle plante de service pour la lutte biologique de conservation contre le puceron jaune de la canne à sucre, a été évaluée. Les espèces prédatrices ont été identifiées par capture directe et/ou observations régulières et l'intensité des dégâts causés par les pucerons a été évaluée par le nombre de colonies. Vingt-quatre espèces prédatrices de pucerons ont été identifiées comme étant hébergées par *T. diversifolia*, et la proximité de cette plante a réduit de 86% le nombre de colonies de *S. flava* dans les bordures de canne à sucre. Ces espèces appartenaient principalement à la famille des Coccinellidae (coccinelles), Syrphidae (syrphes), Chrysopidae (chrysopes vertes) et Dolichopodidae (mouches à longues pattes). Il s'agit du premier article évaluant le potentiel de *T. diversifolia* en tant que plante de service dans les cultures de canne à sucre pour la lutte contre les ravageurs.

**Mots clés :** Canne à sucre / lutte biologique / plante de service / *Sipha flava* / *Tithonia diversifolia*

## 1 Introduction

The Yellow Sugarcane Aphid (YSA) *Sipha flava* (Hemiptera: Aphididae) is a pest insect originated from North America that arrived in Africa in 2006 (Abdelmajid, 2008) and reached the sugarcane plantations of Tanzania during the last decade, where it became a growing problem. The pest is currently managed using pesticides such as neonicotinoids, but the efficacity of this chemical control tends to decrease due to the development of resistance in the aphid population (Dedryver *et al.*, 2010). To manage pests without affecting

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**Fig. 1.** *Tithonia diversifolia* bordering a sugarcane field.
***Fig. 1.*** *Tithonia diversifolia* en bordure d'un champ de canne à sucre.

the environment ability to provide ecosystem services and to prevent inducing chemical resistance in pest population, alternative control ways have to be implemented (Tilman *et al.*, 2002). Unlike chemical control, biological control is able to manage pest using beneficial arthropods that are already present in the field or by massively release them in the fields. This biological control can be increased by introducing new species, but this technique requires important knowledge of both the introduced species and the receiving environment in order to prevent attack on non-target species that can eventually end up on their decline (Louda *et al.*, 2003). An effort-effective way to use biological control is to conserve the native species. Most beneficial arthropods regarding aphid management also feed on pollen, their population can be preserved and encouraged with the help of banker plants at the vicinity of the major crop. These companion plants provides food (nectar) and shelter for beneficial arthropods (Huang *et al.*, 2011). *Tithonia diversifolia* (Fig. 1) is a flowering plant from the Asteraceae family native from Central America but widespread in the world as an invasive species. Yet, it is of no threat to the crops as the plant is rarely found within the plots in large number, and can be easily removed (Husson *et al.*, 2010). Such invasiveness has not been observed at TPC in the estate over the last 25 yr. The ecology of *T. diversifolia* varies greatly depending on the climate, it can be annual or perennial and its flowering period remain inconstant yet its interest on biological control depends mostly to its capacity to provide pollen and nectar. In lower Kilimanjaro region, *T. diversifolia* can be found in scarce number along rivers, roads or planted in vicinity of small scale farmer crops. The role of semi-natural habitat in increasing species richness in the fields have been proven (Billeter *et al.*, 2007) and suggests that landscape diversity increase the biological control (Gardiner *et al.*, 2009). As well as being used as insecticidal plant when macerated (Dougoud *et al.*, 2019), green manure (Jama *et al.*, 2000), and being widely used for pasture in South America (Mauricio, 2017), *T. diversifolia* growing agronomic interest could be extended to pest management as a banker plant for agroecological diversification (Donatti-Ricalde *et al.*, 2018). Studies on *T. diversifolia* as banker plant for conservation biocontrol is very scarce and the only referenced article found by the authors was produced by Calvert *et al.*, 2019. In fact despite the interesting role of *T. diversifolia* in hosting anthocorid predators of thrips, this plant also attracted the thrips and made this plant species not applicable as a banker plant in greenhouse crops. Yet the need to introduce flowering plants in this Northern-Tanzanian sugarcane plantations to increase the biological control has been stressed several times (Jepson, 1956; Katundu, 1999 ; Goebel, 2021), so following their instructions *T. diversifolia* hedges have been implemented in the early 2000 at TPC sugarcane estate (Katundu, 1999). This study aims at evaluating the potential of *T. diversifolia* as a banker plant for the natural enemies of the Yellow Sugarcane Aphid *S. flava* and its edge effect in Tanzanian sugarcane fields.

## 2 Material and methods

Surveys for insects and the Yellow Sugarcane Aphid (YSA) *S. flava* (Homoptera: Aphididae) were conducted in Moshi, Tanzania (3°31'59.2"S 37°19'37.5"E) monthly from May to August 2023 in the morning (8 am-11 am) after the long rainy season, with daily temperature ranging from 15 °C to 25 °C. During this period *T. diversifolia* remained systematically flowering. In the Northern part of Tanzania, the climate is semi-arid. The fields are located on a plateau at an average altitude of 800 m. Within the 15,000 ha of properties, 7,800 ha are cultivated with sugarcane monoculture. In between the sugarcane fields, the presence of flower is very scarce, represented by ornamental flowers around the water pump stations, flamboyant trees along the main road and few *T. diversifolia* hedges remaining in the Northern part of the

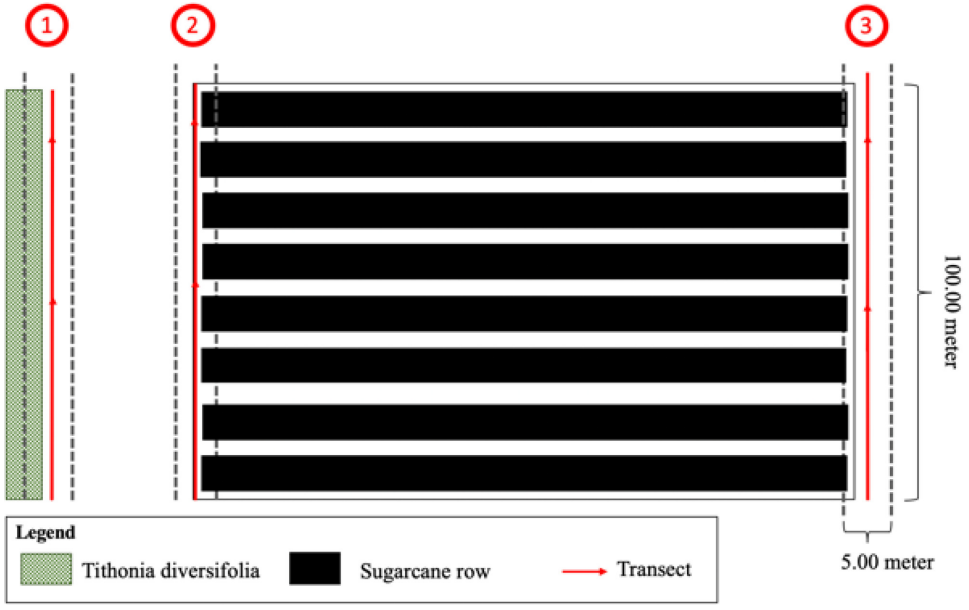


**Fig. 2.** Scheme of the monthly triple transect realized per field studied.
***Fig. 2.*** Schéma du triple transect mensuel réalisé par champ étudié].

property. The cultivated area is surrounded by TPC's "Namalok" nature reserve on the South, the Pangani and Kikuletwa rivers on the West, and villages of small scale farmers on the East. The sugarcane complex is arbitrarily divided in 3 areas (East, North, South). For both East and North area, two fields with *T. diversifolia* hedges in their vicinity were selected. In East area (fields K3 & K5), both *T. diversifolia* hedges are oriented South-North, separated from the sugarcane fields by a 15 meters dirt pathway alternately occupied by grass or bare soil depending on herbicide applications. In North area, the *T.diversifolia* bordering the field N51 is oriented South-North while the one bordering the field N52 is oriented East-West. Both hedges are close (<5 meters) to the fields they are bordering. All the fields are comparable in size, from 30 ha to 44 ha and benefit from the same system of overhead sprinkler irrigation. For all rows of *T. diversifolia* along each field studied a transect of 100 meters was observed by spending 5 min every ten meters for a total duration of 50 min. Every insect in direct contact with *T. diversifolia* was recorded, whether it was on the leaves or flowers. For each new species encountered, the first individual was captured for further identification at the laboratory under a stereomicroscope based on the previous entomologist consultancy report (Conlong, 2019; Goebel, 2021). When necessary, additional captures were carried out to confirm species identification by consulting keys (Chen *et al.*, 2013; Hounkpati, 2005; John *et al.*, 2017; Jones *et al.*, 2002; Siaumar et Kamal, 1977; Speight et Sarthou, 2012; Tomaszewska et Szawaryn, 2016) and contacting specialist entomologists, or the identification was limited to genus level, then were confirmed by FR Goebel, an entomologist from the French Agricultural Research Centre for International Development (CIRAD). The insects already identified were just counted and photographed. The same protocol of transect was applied for both the closest and farthest sugarcane field edges to the Tithonia rows, resulting in a triple transect per field studied (Fig. 2). Only the insects in direct contact with sugarcane were counted. Particular attention was paid to checking the underside of sugarcane blades, as this is where aphids are found. The aphids were counted by colonies; a colony is defined by the homogenous aggregation of at least 2 individuals. Based on laboratory rearing, all the black ladybug larvae were considered as belonging to the species *Hippodamia variegata*, and all hairy white larva as belonging to *Scymnus suturalis*. Only insect species were considered in this study even though numerous araneid species were also encountered. All the statistical analysis were realized on RStudio (version 2023.03.0+386). As no variable followed normal law ($p<0.05$ at Shapiro test), the equality of the medians were tested by Wilcoxon test. The species diversity were quantified using the Shannon diversity index H' (Shannon et Weaver, 1948). The species evenness of the communities was quantified with the Pielou's evenness index E (Pielou, 1966).

## 3 Results

Within the 16 triple transects observed on 4 different *T. diversifolia* rows, 64 insect species were identified. 24 of them were known as aphid predators (Tabs. 1–4): 13 Coccinellidae, 1 Chrysopidae, 1 Dolichopodidae, 1 Formicidae, 2 Mantidae, 1 Staphylinidae, 5 Syrphidae (Fig. 3). These predators represent 46.5% of the observed species on *T. diversifolia*. The species diversity greatly depends on the *T. diversifolia* location (Tab. 5). The major species observed is *Epilachna varivestis* (Coleoptera: Coccinellidae), a phytophagous ladybeetle that has never been observed in sugarcane fields and is therefore not a threat to this crop. The most observed aphid predator is *Condylostylus* sp. (Diptera: Dolichopodidae), a long-legged fly that represent 29.1% of the observed insects. The aphid predators from the Coccinellidae family represent 9.8% of the

**Table 1.** Aphid predators observed during the K3 transects.
***Tableau 1.*** *Prédateurs de pucerons observés durant les transects K3.*

| Plant observed | Nb of transects | Aphid predator species observed | Average adult predator/ transect (min-max) | Average predator preimaginal instar per transect (min-max) | Average YSA colonies observed (min-max) |
|---|---|---|---|---|---|
| Tithonia diversifolia K3 | 4 | *Exochomus concavus** | 1.75 (0-5) | – | – |
| | | *Parexochomus nigromaticulus* | 0.25 (0-1) | – | |
| | | *Hippodamia variegata** | 0.75 (0-3) | – | |
| | | *Scymnus suturalis** | 0.50 (0-2) | – | |
| | | *Scymnus frontalis** | 1.00 (0-2) | – | |
| | | *Ortalia ochracea* | 0.75 (0-2) | – | |
| | | *Harmonia axyridis** | 0.25 (0-1) | – | |
| | | *Chilocorus circumdatus* | 0.25 (0-1) | – | |
| | | *Ischiodon aegyptius** | 2.25 (0-6) | – | |
| | | *Eristalis sp.* | 0.50 (0-2) | – | |
| | | *Condostylus* sp.* | 8.75 (2-17) | – | |
| | | *Paederus littoralis* | 0.25 (0-1) | – | |
| | | *Mantis* sp. | 1.25 (0-5) | – | |
| | | **Total** | **18.50 (7-31)** | – | |
| Sugarcane field K3 (Closest side to Tithonia) | 4 | *Brumoides suturalis* | 1 (0-4) | – | 34.75 (4-101) |
| | | *Exochomus concavus** | 0.25 (0-1) | – | |
| | | *Hippodamia variegata** | 0.25 (0-1) | 0.75 (0-2) | |
| | | *Scymnus suturalis** | 0.25 (0-1) | – | |
| | | *Scymnus frontalis** | 0.25 (0-1) | – | |
| | | *Cryptolaemus montrouzieri* | 0.25 (0-1) | – | |
| | | *Ischiodon aegyptius** | 1.75 (0-6) | – | |
| | | *Condostylus* sp.* | 4.25 (1-9) | – | |
| | | **Total** | **8.25 (5-15)** | **0.75 (0-2)** | |
| Sugarcane field K3 (Farthest side to Tithonia) | 4 | *Brumoides suturalis* | 1.00 (0-4) | – | 167 (25-291) |
| | | *Exochomus concavus** | 1.25 (0-4) | – | |
| | | *Hippodamia variegata** | 0.25 (0-1) | 0.75 (0-2) | |
| | | *Cheilomenes sulphurea* | 0.25 (0-1) | – | |
| | | *Harmonia axyridis** | 0.25 (0-1) | – | |
| | | *Scymnus suturalis** | – | 0.25 (0-1) | |
| | | *Ischiodon aegyptius** | 0.25 (0-1) | 1.50 (0-5) | |
| | | *Chrysoperla rufilabris* | 0.50 (0-2) | 0.50 (0-2) | |
| | | *Condostylus* sp.* | 1.50 (1-3) | – | |
| | | **Total** | **5.25 (4-6)** | **3.00 (1-6)** | |

* Species found both in *T.diversifolia* and the bordering sugarcane field.

observed insects, with 44.2% of the observed Coccinellidae being *Exochomus concavus*. In the East area (K3 and K5), the species were more evenly distributed (E>0.80) than in the North area (E<0.60). In N51, *E. varivestis*, the pest of *T. diversifolia*, was the dominant species (46% of the observed species), whereas in N52 it was the aphid predator *Condostylus* sp. The *T. diversifolia* rows and their surrounding sugarcane fields shared a variable proportion from 3 to 7 shared aphids predator species (Tabs. 1 and 3). The only larvae identified in *T. diversifolia* is the pest *E. varivestis*. For each sugarcane field, the closest edges were less infested by *S. flava* than the farthest edges (reduction of 86.6%). Regarding the total study, the Yellow Sugarcane Aphid median from the sugarcane field edges bordering *T. diversifolia* (3.5 colonies) were significantly (p= 0.001) lower than the one from the farthest edges (64.5 colonies) (Fig. 4). Yet no significant difference in predator quantity was observed in between edges of sugarcane fields (p= 0.57). However, in total, the median YSA per predator ratio is significantly higher (p= 0.001) in the sugarcane edges at the opposite of *T. diversifolia* (10.87 YSA per predator) than in the adjacent edges (0.42 YSA per predator) (Fig. 5).

## 4 Discussion

The diversity of aphid predators hosted by *T. diversifolia* makes it an effective banker plant for beneficial arthropods protecting sugarcane fields. In addition, random observations on other *T. diversifolia* revealed the presence of other insects from the family of Coccinellidae (*Chilocorus stigma*, *Cryptolaemus montrouzieri*, *Psyllobora vigintimaculata, Tenuisvalvae notata*). The absence of any aphid predator larva in *T. diversifolia* suggests that aphid predators might lay their eggs in the sugarcane fields. And the development of these eggs is very important for consumption of aphid's larvae. As the number of predators per YSA is significantly higher in

**Table 2.** Aphid predators observed during the K5 transects.
***Tableau 2.*** *Prédateurs de pucerons observés durant les transects K5.*

| Plant observed | Nb of transects | Aphid predator species observed | Average adult predator/ transect (min-max) | Average predator preimaginal instar per transect (min-max) | Average YSA colonies observed (min-max) |
|---|---|---|---|---|---|
| Tithonia diversifolia K5 | 4 | *Exochomus concavus** | 0.25 (0-1) | – | – |
| | | *Parexochomus nigromaticulus** | 0.25 (0-1) | – | |
| | | *Cheilomenes sulphurea** | 0.25 (0-1) | – | |
| | | *Ischiodon aegyptius** | 3.00 (0-8) | – | |
| | | *Eristalis* sp. | 0.25 (0-1) | – | |
| | | *Condostylus* sp.* | 2.25 (0-6) | – | |
| | | **Total** | **6.25 (3-10)** | – | |
| Sugarcane field K5 (Closest side to Tithonia) | 4 | *Exochomus concavus** | 0.25 (0-1) | – | 6.25 (0-13) |
| | | *Parexochomus nigromaticulus** | 0.25 (0-1) | – | |
| | | *Hippodamia variegata* | 0.25 (0-1) | – | |
| | | *Ischiodon aegyptius** | 0.75 (0-3) | – | |
| | | *Condostylus* sp.* | 0.50 (0-1) | – | |
| | | **Total** | **2 (1-3)** | – | |
| Sugarcane field K5 (Farthest side to Tithonia) | 4 | *Parexochomus nigromaticulus** | 0.50 (0-2) | – | 81.25 (18-197) |
| | | *Hippodamia variegata* | 0.75 (0-2) | 0.25 (0-1) | |
| | | *Scymnus suturalis* | 0.50 (0-2) | 0.25 (0-1) | |
| | | *Cheilomenes sulphurea** | 0.25 (0-1) | – | |
| | | *Cryptolaemus montrouzieri* | 0.25 (0-1) | – | |
| | | *Psyllobora vigintiduopunctata* | 0.25 (0-1) | – | |
| | | *Ischiodon aegyptius** | – | 1.00 (0-4) | |
| | | *Syritta* | 0.50 (0-2) | – | |
| | | *Condostylus* sp.* | 2.00 (0-7) | – | |
| | | **Total** | **5.00 (1-11)** | **1.50 (0-5)** | |

* Species found both in *T.diversifolia* and the bordering sugarcane field.

**Table 3.** Aphid predators observed during the N51 transects.
***Tableau 3.*** *Prédateurs de pucerons observés durant les transects N51.*

| Plant observed | Nb of transects | Aphid predator species observed | Average adult predator/ transect (min-max) | Average predator preimaginal instar per transect (min-max) | Average YSA colonies observed (min-max) |
|---|---|---|---|---|---|
| Tithonia diversifolia N51 | 4 | *Exochomus concavus** | 6.00 (5-8) | – | – |
| | | *Parexochomus nigromaticulus* | 1.25 (0-5) | – | |
| | | *Brumoides suturalis* | 0.25 (0-1) | – | |
| | | *Cheilomenes lunata* | 1.50 (0-4) | – | |
| | | *Cheilomenes sulphurea* | 1.25 (0-4) | – | |
| | | *Chilocorus* sp. | 0.75 (0-3) | – | |
| | | *Ischiodon aegyptius** | 1.75 (0-4) | – | |
| | | *Syritta* sp. | 1.50 (1-2) | – | |
| | | *Eristalis* sp. | 0.75 (0-2) | – | |
| | | *Mesembrius* sp. | 2.00 (0-5) | – | |
| | | *Eristalinus* sp. | 1.75 (0-7) | – | |
| | | *Chrysoperla rufilabris* | 0.25 (0-1) | – | |
| | | *Condostylus* sp.* | 14.75 (2-32) | – | |
| | | **Total** | **33.75 (18-49)** | – | |
| Sugarcane field N51 (Closest side to Tithonia) | 4 | *Exochomus concavus** | 0.50 (0-1) | – | 2.25 (0-6) |
| | | *Scymnus suturalis* | 0.50 (0-2) | – | |
| | | *Scymnus frontalis* | 0.25 (0-2) | – | |
| | | *Hippodamia variegata* | – | 0.50 (0-1) | |
| | | *Ischiodon aegyptius** | – | 0.25 (0-1) | |
| | | *Condostylus* sp.* | 4.75 (3-7) | – | |
| | | **Total** | **6 (3-10)** | **0.75 (0-2)** | |
| Sugarcane field N51 (Farthest side to Tithonia) | 4 | *Exochomus concavus** | 0.25 (0-1) | – | 37.25 (2-68) |
| | | *Scymnus suturalis* | – | 0.25 (0-1) | |
| | | *Condostylus* sp.* | 5.50 (1-14) | – | |
| | | **Total** | **5.75 (1-14)** | **0.25 (0-1)** | |

* Species found both in *T.diversifolia* and the bordering sugarcane field.

the closest sugarcane field edges of *T. diversifolia*, and as the number of aphids is significantly higher in the closest sugarcane field edges of *T. diversifolia*, we can conclude that *T. diversifolia* is protecting the edges of sugarcane fields by hosting aphid predators that consume both the nectar from their flower and the aphids nearby, in addition to laying eggs in the sugarcane fields. The presence in between sugarcane plots could slow down the aphid spreading through the sugarcane fields.

Additionally to the aphid predators, some moth parasitoid species have been observed (*Brachymeria kassalensis*, *Enicospilus purgatus*), meaning that *T. diversifolia* could play a role in sugarcane protection from Lepidoptera moth borers and leaf feeders, such as *Sesamia calamistis*, *Spodoptera* sp., *Eldana saccharina*, even though those assertions remain speculative as no literature supports these host-prey possibility. Numerous species of parasitoid wasp (Fig. 6) from the scoliidae family, such as *Campsomeriella caelebs*, *Campsomeriella madonensis*, *Campsomeris mansueta*, *Cathimeris sjostedti*, *Megameris pseudofasciatipennis*, *Megameris soleata*, were already observed feeding on *T. diversifolia* (Katundu, 1999). This family of wasp are known to be good parasitoids of white grubs. Even though managing this plant in all infested sugarcane areas could enhance biological control, *T. diversifolia* is sometimes reported as an invasive species and should therefore not be introduced into new habitats until further research. However, concerning places where *T. diversifolia* has settled for decades and has never become an invasive weed in the fields even when it has been planted next to the crops, such as in TPC, promoting *T. diversifolia* semi-natural hedges could address a major factor restricting insect biological control in wide sugarcane monoculture area: the absence of flowers. Regarding the results of the experiments, planting *T. diversifolia* around sugarcane fields could act as semi-natural barrier slowing down the spread of YSA during their outbreak cycle in between rainy seasons. These hedges can be easily managed with the machinery used for sugarcane plantation and slashed when necessary. In the Eastern Africa context, the overgrowth of *T. diversifolia* could be manually reduced by cutting to feed the cattle of the herders, mainly Maasaï people, frequently met in TPC during their pastoralism activities. Because of its allelopathic properties inhibiting the germination and growth of other plant species (Kato-Noguchi, 2020), *T. diversifolia* could provide a natural weed control limiting the usage of herbicide. This study is the first to evaluate *T. diversifolia* in its capacity to increase biological control in sugarcane fields. Regarding its widespread habitat over the world, the applications could be important, particularly in African sugar estates. Therefore, additional investigations are needed to evaluate the potential of protection provided by *T. diversifolia* as a companion plant to sugarcane fields in an agroecological management plan.

**Table 4.** Aphid predators observed during the N52 transects.
***Tableau 4.*** *Prédateurs de pucerons observés durant les transects N52.*

| Plant observed | Nb of transects | Aphid predator species observed | Average adult predator/ transect (min-max) | Average predator preimaginal instar per transect (min-max) | Average YSA colonies observed (min-max) |
|---|---|---|---|---|---|
| Tithonia diversifolia N52 | 4 | *Exochomus concavus* | 1.50 (0-5) | – | – |
| | | *Scymnus suturalis** | 0.50 (0-2) | – | |
| | | *Scymnus frontalis* | 0.25 (0-1) | – | |
| | | *Cheilomenes lunata* | 0.25 (0-1) | – | |
| | | *Cheilomenes sulphurea* | 0.50 (0-2) | – | |
| | | *Cheilomenes propinqua* | 0.50 (0-2) | – | |
| | | *Chilocorus* sp. | 0.25 (0-1) | – | |
| | | *Ischiodon aegyptius** | 0.50 (0-2) | – | |
| | | *Syritta* sp.* | 1.75 (0-6) | – | |
| | | *Eristalis* sp. | 0.25 (0-1) | – | |
| | | *Condostylus* sp.* | 37.75 (8-64) | – | |
| | | *Paederus littoralis* | 0.25 (0-1) | – | |
| | | *Mantis religiosa* | 0.25 (0-1) | – | |
| | | **Total** | **44.50 (11-78)** | – | |
| Sugarcane field N52 (Closest side to Tithonia) | 4 | *Scymnus suturalis** | 0.25 (0-1) | 0.50 (0-2) | 3.50 (0-13) |
| | | *Syritta* sp.* | 0.50 (0-2) | – | |
| | | *Mesembrius* sp. | 0.25 (0-1) | – | |
| | | *Condostylus* sp.* | 24.00 (2-35) | – | |
| | | **Total** | **25 (2-36)** | **0.50 (0-2)** | |
| Sugarcane field N52 (Farthest side to Tithonia) | 4 | *Parexochomus nigromaticulus* | 0.25 (0-1) | – | 63.75 (23-143) |
| | | *Hippodamia variegata* | 0.25 (0-1) | 0.50 (0-2) | |
| | | *Scymnus suturalis** | 0.25 (0-1) | 7.25 (0-29) | |
| | | *Cryptolaemus montrouzieri* | 0.25 (0-1) | – | |
| | | *Ischiodon aegyptius** | – | 1.00 (0-4) | |
| | | *Chrysoperla rufilabris* | – | 0.25 (0-1) | |
| | | *Condostylus* sp.* | 1.75 (1-3) | – | |
| | | **Total** | **2.75 (1-6)** | **9.00 (0-30)** | |

* Species found both in *T. diversifolia* and the bordering sugarcane field.

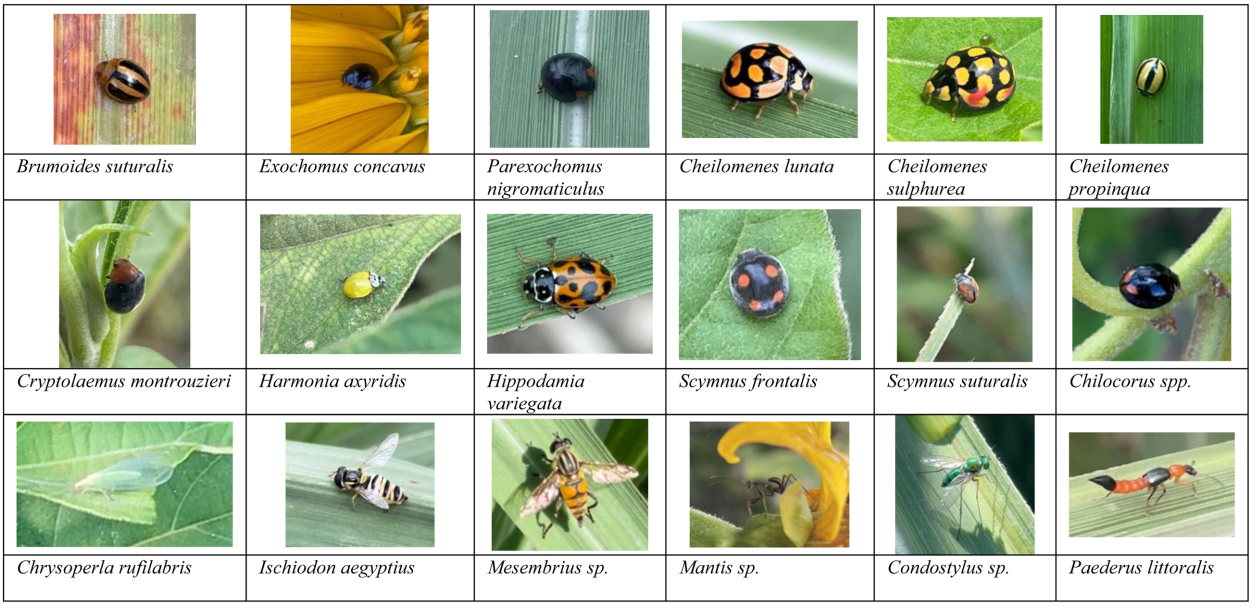


**Fig. 3.** Major aphid predators detected during *T. diversifolia* monitoring.
***Fig. 3.*** Principaux prédateurs de pucerons détectés lors du suivi de *T. diversifolia*.

**Table 5.** Major insect species observed on *Tithonia diversifolia* per location.
***Tableau 5.*** *Principales espèces d'insectes observées sur* Tithonia diversifolia *par site.]*

| Location | Shannon index (H') | Pielou index (E) | Major species | Functional role | Proportion |
|---|---|---|---|---|---|
| Tithonia K3 | 2.85 | 0.80 | *Condylostylus* sp. | Predator | 0.26 |
| | | | *Epilachna varvivestis* | Pest Tithonia | 0.11 |
| | | | *Enicospilus purgatus* | Moth Parasitoid | 0.06 |
| Tithonia K5 | 2.45 | 0.83 | *Epilachna varvivestis* | Pest Tithonia | 0.23 |
| | | | *Ischiodon aegyptius* | Predator | 0.14 |
| | | | *Condylostylus* sp. | Predator | 0.10 |
| Tithonia N51 | 2.06 | 0.59 | *Epilachna varvivestis* | Pest Tithonia | 0.46 |
| | | | *Condylostylus* sp. | Predator | 0.14 |
| | | | *Apis mellifera* | Pollinator | 0.11 |
| Tithonia N52 | 1.64 | 0.50 | *Condylostylus* sp. | Predator | 0.57 |
| | | | *Apis mellifera* | Pollinator | 0.15 |
| | | | *Epilachna varvivestis* | Pest Tithonia | 0.09 |

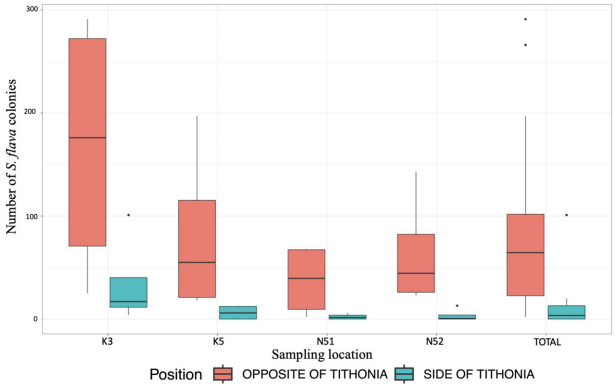


**Fig. 4.** Average number of *S. flava* in sugarcane rows in the vicinity of *T. diversifolia.*
***Fig. 4.*** Nombre moyen de *S. flava* dans les rangs de canne à sucre à proximité de *T. diversifolia*.

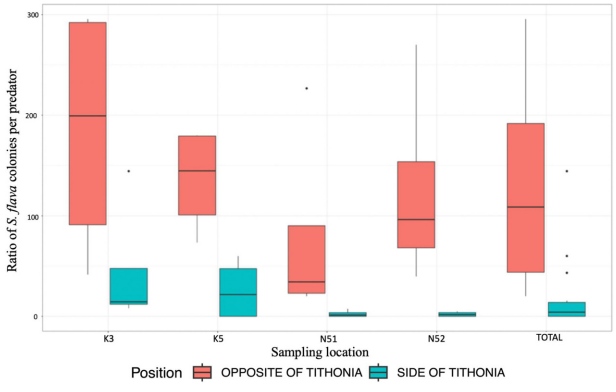


**Fig. 5.** Average ratio of *S. flava* per aphid predator in the vicinity of *T. diversifolia.*
***Fig. 5.*** Ratio moyen de *S. flava* par prédateur de pucerons à proximité de *T. diversifolia*.

**Fig 6.** Campsomeriella sp. observed on T. diversifolia.
***Fig 6.*** Campsomeriella sp. observé sur T. diversifolia.gr

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## Conflicts of interest

No conflict of interest has been identified. This study has been made during an internship funded by the sugarcane company TPC Limited.

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