Original article

# The mango tree in central and northern Benin: cultivar inventory, yield assessment, infested stages and loss due to fruit flies (Diptera Tephritidae)

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**The mango tree in central and northern Benin: cultivar inventory, yield assessment, infested stages and loss due to fruit flies (Diptera Tephritidae).**

**Abstract — Introduction**. The mango tree is of prime importance to the rural economy of central and northern Benin since it provides food and crucial nutriments at the end of the dry season. However, mango producers in Benin are confronted with two problems that are closely connected: deterioration of fruit quality by fruit flies and the inadequacy of postharvest methods. In the Sudanian zone of Benin, fruit flies (Diptera Tephritidae) are highly responsible for major production losses. **Materials and methods**. An inventory of all present cultivars and yields of main mango cvs. (Gouverneur, Eldon, Dabshar, Kent, Smith, Keitt and Brooks) was carried out in Benin on 7 000 fruits near Parakou (Borgou) during the years 2005 and 2006. Sampling of 3 000 young fruits (length range 13–26 mm) was carried out in 2006 in order to detect some very early tephritid attacks. A loss assessment of pre-ripening and ripening fruits was also carried out on 7 750 fruits in 2006. **Results and discussion**. We identified 29 cultivars in the district of Borgou where 75% of the mango orchards of Benin are situated. Most of these use the 'gatherer' production system. The early Gouverneur cultivar had the lowest yield (1.8 $t \cdot ha^{-1}$), and the late Brooks cultivar had the highest yield (10.4 $t \cdot ha^{-1}$). Small and immature young fruits allowed development of both *C. cosyra* and *B. invadens* in February and March, *i.e.*, before the mango season itself: this result could be a useful result for pest control. For the pre-ripening and ripening stages, average losses due to tephritid varied from 0.34 $t \cdot ha^{-1}$ to 6.5 $t \cdot ha^{-1}$ depending on cultivar type, resulting in considerable loss of income for small planters. Taking all cultivars together, losses stood at 17% in early April and exceeded 70% at mid-June. By the middle of the crop year, over 50% losses were recorded. The seasonal cultivar Eldon and late cultivars (Keitt and Brooks) were the most infested. **Conclusion**. In the Sudanian zone of Benin, the two main species of Tephritidae that have a high economic impact on mango trees are *B. invadens* and *C. cosyra*. Our preliminary observations and calculations will be used in a forthcoming article to calculate the economic injury level of these fruit flies.

**Benin / *Mangifera indica* / plant developmental stages / Tephritidae / *Bactrocera invadens* / *Ceratitis cosyra* / varieties / yields / insect stings / crop losses**

**Le manguier dans le centre et le nord du Bénin : inventaire des cultivars, estimation des rendements, stades touchés et pertes dues aux mouches des fruits (Diptera Tephritidae).**

**Résumé — Introduction**. Le manguier occupe une place particulièrement importante dans l'économie rurale des zones centrales et septentrionales du Bénin. Pendant la fin de la saison sèche, la mangue constitue un apport nutritionnel fondamental par sa forte teneur en nutriments. Mais, au Bénin, les producteurs de mangues sont confrontés à deux contraintes étroitement liées l'une à l'autre : défaut de qualité du fruit imputable aux mouches des fruits et insuffisance de techniques adéquates de « post-récolte ». Dans la zone soudanienne béninoise, les mouches des fruits (Diptera Tephritidae) sont la contrainte majeure responsable de pertes considérables de production. **Matériel et méthodes**. L'inventaire des cultivars présents au Mali et les estimations de rendements des principaux cultivars de manguier (Gouverneur, Eldon, Dabshar, Kent, Smith, Keitt, Brooks) ont été menés sur 7000 fruits autour de Parakou durant les années 2005 et 2006. Des échantillonnages de 3000 petits fruits (de 13 mm à 26 mm) ont été réalisés en 2006 afin de savoir quels étaient les stades les plus précoces à être attaqués. Des estimations de pertes au niveau des stades de pré-maturité et maturité de 7 750 fruits ont été également faites en 2006. **Résultats et discussion**. Nous avons identifié 29 cultivars dans le département du Borgou qui concentre environ 75 % des vergers de manguiers du Bénin. La plupart d'entre eux appartiennent à un système de production de « type cueillette ». Le cultivar précoce Gouverneur (1,8 $t \cdot ha^{-1}$) a eu le plus faible rendement et le cultivar tardif Brooks a eu le rendement le plus élevé (10,4 $t \cdot ha^{-1}$). Les petits fruits immatures ont permis le développement complet de *C. cosyra* comme de *B. invadens* durant les mois de février et mars, soit bien avant la campagne mangue ; cela pourrait avoir des applications sur la lutte. Pour les stades de pré-maturité et maturité des fruits, les pertes moyennes dues aux Tephritidae ont varié de 0,34 $t \cdot ha^{-1}$ à 6,5 $t \cdot ha^{-1}$ selon les cultivars et elles ont occasionné une perte de revenus considérable pour les petits planteurs. En prenant en compte la moyenne de tous les cultivars, les pertes atteignent 17 % en début d'avril pour dépasser 70 % à la mi-juin. Plus de 50 % de pertes ont été enregistrés au milieu de la campagne de mangue. Le cv. de saison Eldon et les cv. tardifs (Keitt, Brooks) ont été les plus infestés. **Conclusion**. Les deux espèces majeures de Tephritidae d'intérêt économique pour le manguier dans le Nord du Bénin sont *B. invadens* et *C. cosyra*. Cette étude préliminaire devrait servir de base au calcul d'un seuil économique de nuisibilité de ces Tephritidae du manguier dans un prochain article.

**Bénin / *Mangifera indica* / stade de développement végétal / Tephritidae / *Bactrocera invadens* / *Ceratitis cosyra* / variété / rendement / piqûre d'insecte / perte de récolte**

## 1. Introduction

National, regional and international trade in tropical fruits is constantly growing, particularly for mangos [1]. Mangos (*Mangifera indica* L.) are a particularly important type of tropical fruit for Sub-Saharan African national and regional economies, as well as for exports. In terms of volume, mango production ranks sixth for fruit exports worldwide, after oranges, bananas, grapes, apples and plantains. Mango imports into Europe have multiplied by five over the past fourteen years, increasing from 42 000 t in 1992 to over 210 000 t in 2006 [2].

The mango tree is rustic and voluminous; it provides both a food staple and protection. In northern Benin, as in other similar agro-ecological zones in neighboring countries, the mango serves as a fruit crop and as a subsistence crop for family farms. As it ripens at the end of the dry season and at the start of the rainy season, the mango is a fundamental source of nutrition for rural populations living in the Sudano-Sahelian regions of West Africa: it is rich in potassium, alpha-carotene, vitamin C and calcium. Increased production and marketing of undamaged mangos are important in reducing poverty, particularly in northern Benin.

Mangos have existed in East Africa since the fourteenth century, but they were only initially reported in West Africa at the beginning of the nineteenth century [3]. Mango trees began to be widespread in West Africa at the end of the nineteenth century, and, at first, grafting on rootstock was used to propagate them. The first mono-embryonic cultivars were multiplied using grafting in coastal countries of French-speaking West Africa, which then gradually spread within the continent [4].

According to our observations and research [5–7] over the past 15 years, the optimum zone for mango trees in West Africa forms an elliptical-shaped area situated in the Sudano-Guinean region, extending from Banjul to Abuja, *i.e.* from eight to forty degrees north latitude. This area broadly covers southern Senegal, Gambia, southern Mali, eastern Guinea, northern Côte d'Ivoire, southern Burkina Faso, northern Ghana, northern Togo, northern Benin and northern Nigeria. This is mainly due to the agro-climatic conditions of the zone. In Sub-Saharan Africa, over 90% of mango production is ensured by small family farms with low financial investment capacity.

In 2006, Benin had an annual Gross National Product (GNP) of 590 US$ per capita, and a GNP growth rate of 1.3% per capita, placing it among the least developed countries. Agriculture is the main sector of activity and contributes 40% of Gross Domestic Product (GDP). In 1994, d'Almeida [8] assessed the area devoted to mango trees in Benin at 1191 ha, total production being 10 166 t, and average yield per ha being 8.5 t. Mango production in Benin is seldom integrated because, between farm and fork, numerous small farmers are involved. Assessments reveal that mango producers are confronted with two closely connected problems: improvement in fruit quality (using effective fruit-fly control) and improvement in post-harvest technical know-how.

In tropical regions, mangos are attacked by fruit flies (Diptera Tephritidae) which wreak great economic devastation in both East Africa [9] and West Africa [5–7]. In 2003, these quarantine insects destroyed an average of 40% of the total mango crop produced yearly in Africa (1.9 Mt) [9]. This figure incorporates seasonal variations. At the end of the crop year, in 2006 as in 2007, over 75% of production in Benin was lost due to fruit flies. The vast numbers of fruit flies are responsible for production loss, which, in turn, greatly diminishes the amount that can be put on the market. Phytosanitary constraints can even lead to bans on exports of this high added-value product. Thus, a huge loss of economic opportunity ensues in terms of income for the populations involved.

In central and northern Benin, about a dozen species of tephritidae colonizing the mango tree have been identified, four of which are economically important: *Ceratitis cosyra* (Walker), *Ceratitis silvestrii* Bezzi, *Ceratitis quinaria* (Bezzi), and *Bactrocera invadens* Drew Tsuruta & White [6]. From these four species, the main two are without a doubt *B. invadens* and *C. cosyra*. Given the economic importance of this pest, numerous research programs have focused on control strategies for use in the orchards. Use of chemical treatment is not an easy option due to financial problems in acquiring it [10]. Several factors lead us to advise against traditional chemical pest control in mango orchards: (i) no active substance is currently approved in West Africa for controlling tropical fruit tree tephritidae, (ii) chemical control also destroys numerous useful allies involved in integrated control (*lato sensu*), (iii) chemical control is a health hazard for both planters and consumers, and (iv) chemical control does not eradicate fruit flies because their pre-imaginal stages are unaffected by the treatment (eggs-larvae in the fruit, pupae in the soil) and also because most of the adults are usually to be found in the peripheral areas surrounding the orchards (Vayssières *et al.*, data unpublished).

In this context, integrated control is particularly suitable for getting rid of the fruit flies without using pesticides. Integrated control has several objectives, principally: (i) significant reduction of the targeted pest population, (ii) lower production costs, (iii) environment-friendly outcomes, and (iv) lasting solutions developed for specific plant health problems.

Setting up an integrated control program entails pest identification and damage assessment. In order to initiate integrated control, technico-economic indicators must exist or must have been defined so that the best decisions can be taken in terms of treatment. The connections between fly population levels and the extent of damage to the fruit will be studied in a forthcoming article using the principle of Economic Injury Level. The present paper describes the different mango cultivars found in northern Benin, the production system typology, different cultivar yields, production price variability, and production loss caused by fruit flies.

## 2. Materials and methods

Mango production data were gathered in the Borgou district (Benin) between January 2005 and January 2007, *i.e.*, two production cycles. The climate type of this zone is Sudanian, characterized by unimodal rainfall (1000–1100 mm yearly). The rainy season usually starts at the end of April and lasts for six months until the end of October.

### 2.1. Mango tree cultivar inventory

Mango orchards are found in dry wooded savannah, interspersed with a few teak plantations which also serve as land ownership indicators. The various cultivars found in Borgou orchards have been identified in 25 orchards monitored since 2005.

### 2.2. Production system typology

A preliminary socio-economic assessment of the mango sector and its principal problems was carried out in 41 mango plantations in the Borgou district during the 2006 crop year. In addition to our preliminary observations in this district, this assessment offers a production system typology.

### 2.3. Observations concerning seven cultivars in the Parakou area

For our experiments on tephritidae, mango orchards were selected at the end of 2004 according to the following criteria, (i) availability of a minimum of 5 ha of grafted mango trees producing fruit, (ii) presence of at least four marketable cultivars, (iii) regular spacing between the trees, (iv) a technical approach guaranteeing non-use of pesticides, and (v) absence of other crops such as cotton in the vicinity, requiring insecticide treatment. In addition to these five points, five mango orchards were selected from the initial 25 orchards monitored since 2005 because these five orchards[1] were planted at the same time (about thirty years before) and, above all, grew the same cultivars.

[1] The five orchards included in the study, belonging to private growers, are located in Tchatchou: lat. 9° 5' 40" N, long. 2° 33' 43" E; in Korobourou: lat. 9° 22' 13" N, long. 2° 40' 16" E, and lat. 9° 23' 15" N, long. 2° 42' 48" E; in Komiguea: lat. 9° 26' 9" N; long. 2° 37' 26" E; and in Kakara: lat. 9° 39' 19" N, long. 2° 40' 27" .

The seven most frequently grafted cultivars (mono-embryonic mango trees, representing over 90% of production), found in the five orchards listed below and ranked in order of ripening, are Gouverneur, Eldon, Dabshar Drahnet (Indian cv.), Kent, Smith, Keitt and Brooks. Yields and production loss due to tephritidae were calculated using successive mango sampling for each of the seven cultivars, and in each of the five orchards.

In order to estimate yield, samples were taken from 350 mango trees (5 orchards × 7 cultivars × 10 trees per year) in early May 2005 and early May 2006 of two crop years, *i.e.*, 700 trees in all. For the Gouverneur cultivar that ripens much earlier, mango samples were collected between late March and early April for both 2005 and 2006.

Losses due to tephritidae were assessed from the beginning of April to mid-June 2006 for the seven main cultivars. Every other week, a sample of 50 fruits (10 each for 5 trees) was gathered for each cultivar, in each site, then kept in shaded rooms to allow the quantification of number of pupae per kg of fruits using a technique developed in 2000 [7]. Mangos belonging to different cultivars and different sites were separated. A total of 7 750 fruits was gathered over six sampling campaigns during the 2006 crop year. The collected fruits were ripe enough to be attacked. It is the reason we have 7750 and not 10500 fruits. We compared the number of pupae per kg of fruits per orchard in order to stress any difference between production systems.

We also sampled 3000 young mangos (length range 13–26 mm) at different early phenological stages of the same cultivar (Eldon) in the same site (Korobourou). At each collection ($n = 15$), we picked 100 fruits on the tree and 100 fruits on the ground during February and March. The objectives were (i) to know if the young mango stages were infested by fruit flies, and (ii) if the oviposition punctures were made on fruits on the tree or fruits laid on the ground. Statistical analysis was done using SAS (2003) and count data were log ($x$ + 1) transformed before analysis to stabilize the variance.

If a tephritid oviposition puncture can be seen on a mango (*figure 1*), whether recent or not, whether for *C. cosyra* or for *B. invadens*, this means that the fruit is lost for the grower because its value is very low. Observations were carried out for batches of 10 fruits. Each pierced mango corresponds to an estimated yield loss of 10%. This link between "puncture = loss" presumes that each puncture leads to the loss of the fruit. This link always holds for production destined for regional and international export as well.

## 3. Results and discussion

### 3.1. Orchard location and graft origin

Mango trees are often located near villages (mango trees in the home garden), but they are also found in uniform or mixed plantations (with citrus fruit, guava trees, etc.). Around villages and isolated farms, "home garden trees" (mangos, citrus fruits, etc.) are often non-grafted and untended, indicating the low degree of intensification of these perennial crops. The orchards were 15 years old on average (range 5–38).

In the Borgou district, we also noticed that planters often have a cashew nut tree plantation next to their mango orchard, which means that they have continual access to fruit from January (when cashew nut production begins) to June (end of mango production). We will explain how this can affect the fruit fly population.

According to our survey on location of mango production in Benin, about 75% of mango orchards are concentrated in the Borgou district. The first economically important cultivar grafts were imported about forty years ago. These were taken from grafted mango trees in the Foulaya-Kindia research unit in Maritime Guinea (an important tropical fruit research and development center in the past) then grafted on rootstock in Benin. Mango trees were grafted in Mali and Burkina Faso from the same source.

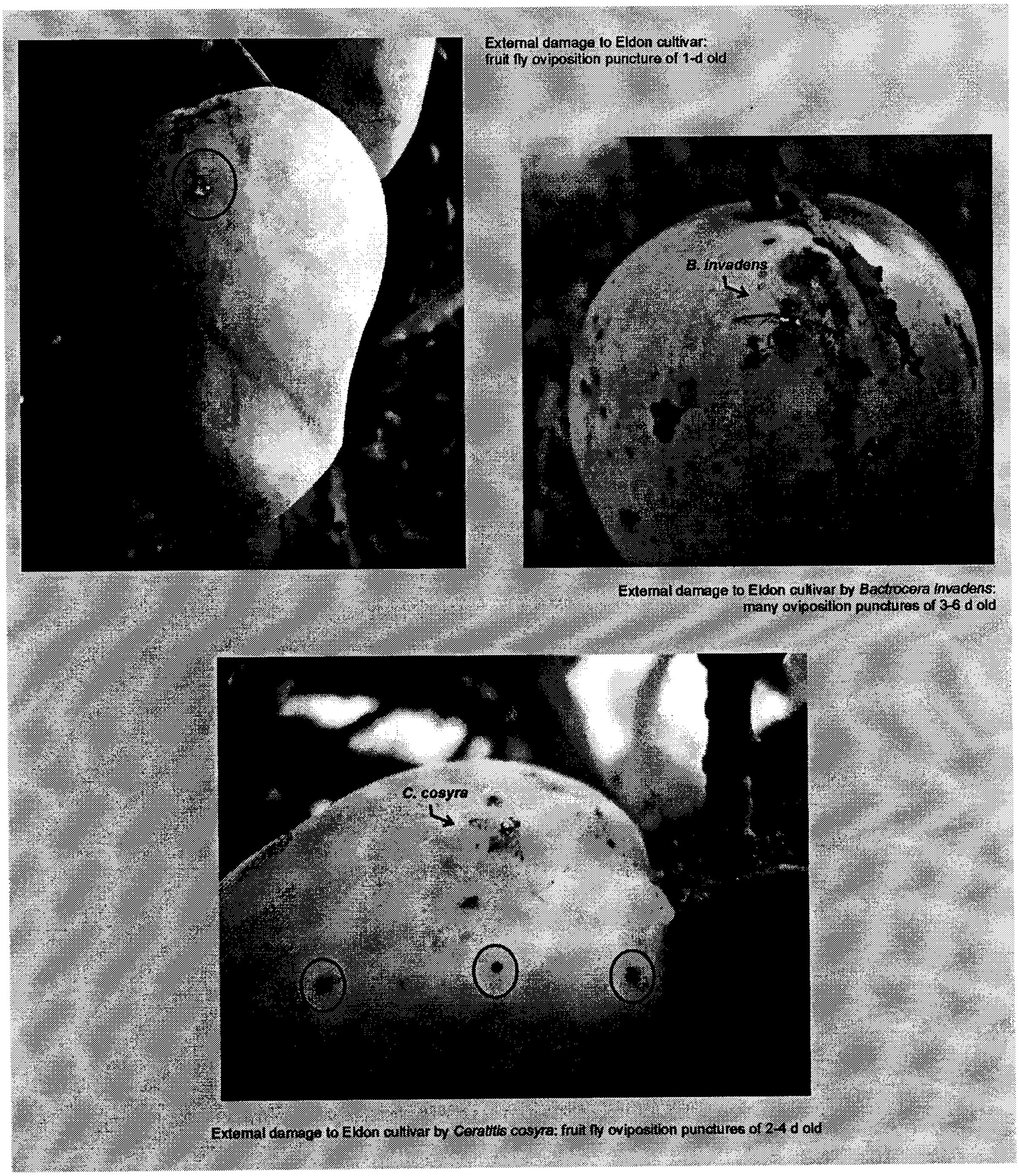
External damage to Eldon cultivar:
fruit fly oviposition puncture of 1-d old
B. invadens
External damage to Eldon cultivar by Bactrocera invadens:
many oviposition punctures of 3-6 d old
C. cosyra
External damage to Eldon cultivar by Ceratitis cosyra: fruit fly oviposition punctures of 2-4 d old

**Figure 1.**

**Table I.**
Seasonal cycle of 14 mango cultivars in the district of Borgou (Benin). Cultivars are ranked by ripening date.

| Mango cultivar | Flowering | Stage 1 | Stage 2 | Pre-ripening | Ripening + harvest |
|---|---|---|---|---|---|
| Gouverneur | Mid-Dec. – mid-Jan. | Begin Jan.– begin Feb. | Begin Feb. – begin Mar. | Mid-Mar. – begin Apr. | Begin Apr. – mid-May |
| Zill | Mid-December – mid-Jan. | Begin Jan. – begin Feb. | Begin Feb. – begin Mar. | Mid-Mar. – begin Apr. | Begin Apr. – mid-May |
| Eldon | Jan. | End Jan. – end Feb. | End Feb. – end Mar. | Begin Apr. – mid-Apr. | Mid-Apr. – end May |
| Ifac 3 | Jan. | End Jan. – end Feb. | End Feb. – end Mar. | Begin Apr. – mid-Apr. | Mid-Apr. – end May |
| Améliorée | Jan. | Begin Feb. – begin Mar. | Begin Mar. – begin Apr. | Mid-Apr. – end Apr. | End Apr. – begin June |
| Haden | Jan. | Begin Feb. – begin Mar. | Begin Mar. – begin Apr. | Mid-Apr. – end Apr. | End Apr. – begin June |
| Dabshar | Jan. | Begin Feb. – begin Mar. | Begin Mar. – begin Apr. | Mid-Apr. – end Apr. | End Apr. – begin June |
| Ruby | Jan. | Begin Feb. – begin Mar. | Begin Mar. – begin Apr. | End Apr. – begin May | Begin May – mid-June |
| Kent | Jan. | Begin Feb. – begin Mar. | Begin Mar. – begin Apr. | End Apr. – begin May | Begin May – mid-June |
| Palmer | Mid-Jan. – mid-Feb. | Mid-Feb. – mid-Mar. | Mid-Mar. – mid-Apr. | Begin May – mid-May | Mid-May – end June |
| Smith | Mid-Jan. – mid-Feb. | Mid-Feb. – mid-Mar. | Mid-Mar. – mid-Apr. | Begin May – mid-May | Mid-May – end June |
| Alphonse | Mid-Jan. – mid-Feb. | Mid-Feb. – mid-Mar. | Mid-Mar. – mid-Apr. | Begin May – mid-May | Mid-May – end June |
| Keitt | Mid-Jan. – end Feb. | Mid-Feb. – end Mar. | Mid-Mar. – end-Apr. | Mid-May – end May | End May – begin July |
| Brooks | Mid-Jan. – end Feb. | Mid-Feb. – end Mar. | Mid-Mar. – end-Apr. | Mid-May – begin June | Begin June – mid-July |

### 3.2. Mango tree cultivar inventory

In the 25 orchards surveyed in the Borgou district, we identified 29 cultivars. We made an inventory of this non-exhaustive list, and gathered the following cultivars roughly ranked by ripening date, from early April to late June: Gouverneur (= Amélie), Zill, Irwin, Tommy Atkins, Muscat (= Julie), Eldon, Ifac 3 (selection from Améliorée du Cameroun), Améliorée du Cameroun, Sabot, Atacora (cv. from Benin), Haden, Dabshar Drahnet, Glazier, Ruby, Cogshall, Miami late, Bedami rouge, Pêche (= Peter Passant), Sensation, Kent, Valencia, Palmer, Springfield, Lippens, Smith, Davis Haden, Alphonse de Goa (Alfonso), Keitt and Brooks. All these grafted cultivars are attacked by fruit flies and can thus carry their larvae.

The seasonal cycles of the 14 most common cultivars among the 29 identified in the Borgou district were specifically observed. This study concerns Gouverneur, Zill, Eldon, Ifac 3, Améliorée du Cameroun, Haden, Dabshar Drahnet, Ruby, Kent, Palmer, Smith, Alphonse de Goa, Keitt and Brooks (*table I*). Of course, in the South of Benin the timing will be a little different due to the different climate.

### 3.3. Production system typology

The only available study on this subject was authored by Bokonon Ganta *et al.* [11] who classified the mango producers of Benin into three groups. The first group (40% of planters) only cultivates mango trees in the home garden. The second group (49%) manages well-organized large orchards. The third group (11%) combines both production types. All these orchards are composed of different mango cvs. with a few citrus ones sometimes.

The research carried out by Boueyi in the Borgou district in 2006 provides data on surface area, use of inputs and cropping practices for 41 orchards. These 41 orchards together cover almost 300 ha: 10% of orchards cover at least 20 ha each, 66% cover between (2 and 19) ha each, and 24% cover less than 2 ha each. The vast majority of planters (95%) use no inputs. Most planters (59%) have no access to development advisory services and 66% of planters market their own production. Local customs are often (44%) responsible for plot attribution.

Taking West Africa as a whole, we differentiated four different mango production systems: (A) gatherer production system

**Table II.**
The three production systems used in mango orchards in Benin and their main characteristics.

| Production system | Average area (ha) | Grafted mango trees (%) | Mechanization | Number of man-days per year | Average yields for all cultivars (except Gouverneur) ($t \cdot ha^{-1}$) | % of market supply | Breakdown of orchards assessed in the Borgou district (%) |
|---|---|---|---|---|---|---|---|
| Type A Gatherer production system | 2 | 0 to 50 | no | < 30 | 3 | 20 | 68 |
| Type B Production system under improvement | 5 | 51 to 75 | no | > 30 but < 60 | 6 | 40 | 22 |
| Type C More intensive production system | ≥ 10 | 76 to 95 | yes | > 60 | 7 | 40 | 10 |

(small orchards only involved in harvesting), (B) production system under improvement (clearing and initial cropping care for medium-sized orchards), (C) more intensive production system (clearing, cropping care, frequent semi-skilled labor, some mechanization, usually in large orchards), and (D) large industrialized orchards (using mechanization, various plant health methods and intensive production). No irrigation was performed for the A, B and C systems.

Orchards were classified into these four systems according to (i) size of orchard, (ii) types of fruit tree (grafted or not), (iii) use of inputs or non-use, (iv) mechanization or not, (v) workforce size and frequency of use (number of man-days), (vi) marketing channels.

We ascertained that only production systems A, B and C are used in Benin (*table II*). We found no type D orchards in the Borgou district (or elsewhere in Benin), despite the fact that this type is quite frequent in northern Côte d'Ivoire (Korhogo area) and in Senegal (Niayes). Our study on yield losses involved three type B orchards, those of Kakara and Komiguea, and two type C orchards, those of Korobourou. These statements are interesting in that most of the fruit supply comes from type B and C orchards where surface areas and yields are highest (*table II*). It should also be stressed that there is no significant difference between production system and intensity of Tephritidae attacks ($F_{1,5}$ = 0.17; $P$ < 0.953). For example, mechanic tilling does not seem to have any effect on fruit fly populations, which is normal for polyvoltine species of tephritid. In fact, tilling is carried out once per year in C orchards and no significant difference in fruit fly infestation was observed in C orchards versus B orchards (*table III*).

## 3.4. Yield estimations for five mango orchards over two crop years

Yield estimations for five mango orchards over two crop years focused on the seven most frequently grafted cultivars; Gouverneur, Eldon, Dabshar, Kent, Smith, Keitt and Brooks. The orchard owners were informed about our project so that they did not anticipate fruit harvesting and thus did not disrupt our study framework, since we were aware that planters often anticipate their mango harvest in order to try to lessen the damage caused by tephritidae.

We counted the fruit produced by the seven main cultivars for two consecutive years. Average mango weight was calculated, plus average number of mangos per tree (*table IV*). The cultivar with the largest fruits is Dabschar, which is saturated with water, and is neither sweet nor tasty. The Gouverneur cultivar, among the smallest, is also called 'Amélie'; it is highly appreciated in Benin and in the sub-region for its pleasant smell and sugar content. Several phenotypes are present here.

**Table III.**
Average number of fruit flies per kg of fruits in five mango orchards studied in Benin.

| Locality | Surface (ha) | Tilling | Number of man-days per year | Average yields ($t \cdot ha^{-1}$) | Production system | Average number of flies per kg of fruits |
|---|---|---|---|---|---|---|
| Tchatchou | 6 | no | ~ 50 | ~ 6 | Type B<br>Production system under improvement | 99 ± 11.03 a |
| Korobourou | ~ 40 | yes | ~ 200 | ~ 7 | Type C<br>More intensive production system | 89 ± 6.39 a |
| Korobourou | 8 | yes | ~ 250 | ~ 7 | Type C<br>More intensive production system | 86 ± 9.70 a |
| Komiguea | 5 | no | ~ 50 | ~ 6 | Type B<br>Production system under improvement | 86 ± 9.77 a |
| Kakara | 7 | no | ~ 50 | ~ 6 | Type B<br>Production system under improvement | 93 ± 14.36 a |

Means followed by the same letter are not significantly different.

**Table IV.**
Production characteristics for the seven main cultivars found in five orchards studied in the Borgou district (Benin, 2005 and 2006 crop years).

| Mango cultivar | Total number of trees in the five orchards | Average weight of a mango (g per cultivar) | Average number of mangos per tree and per cultivar | Average yield ($kg \cdot ha^{-1}$) | Average farm-gate price for 1 kg mangos (FCFA) |
|---|---|---|---|---|---|
| Gouverneur | 474 | 254 ± 56 | 71 ± 19 | 1 803 | 70 |
| Eldon | 3 478 | 356 ± 155 | 249 ± 108 | 8 864 | 50 |
| Dabshar | 177 | 534 ± 164 | 54 ± 19 | 2 883 | 30 |
| Kent | 1 070 | 494 ± 127 | 120 ± 43 | 5 928 | 35 |
| Smith | 152 | 444 ± 85 | 205 ± 76 | 9 102 | 38 |
| Keitt | 76 | 388 ± 128 | 157 ± 63 | 6 091 | 43 |
| Brooks | 185 | 252 ± 113 | 413 ± 121 | 10 407 | 20 |

Yields were calculated using the data in this same table (*table IV*), taking an average density of 100 trees per ha. These are estimations, given the unequal yields of the various cultivars. Yields are, however, comparable with other yields obtained for the same cultivars in other orchards (Sirarou, Tamarou, N'Dali, Ina, etc.) in the northern part of this district. As in other countries of West Africa, the early Gouverneur cultivar has the lowest yield ($1.8\ t \cdot ha^{-1}$) and the late Brooks cultivar has the highest yield ($10.4\ t \cdot ha^{-1}$). The cultivars with the highest market value such as Kent and Keitt, destined for export, have an average yield of $6\ t \cdot ha^{-1}$. Mango tree yields vary considerably from one year to the next, because production is high every other year – which is a well-known phenomenon [12]. In Benin, mango production was high in 2005 and 2007, but lower in 2006 and 2008.

## 3.5. Market value of mangos in 2006

Market values of the different cultivars, according to production and harvesting periods, show that, in the middle of the crop year when production is at its peak, the average weighted price is at its lowest level because supply is high and demand is met (*table V*). Depending on the cultivar, the average price per kg of mangos fluctuates between 20 FCFA (Kent, Smith, Brooks) and 40 FCFA (Gouverneur).

**Table V.**
Mango farm-gate price (FCFA) variability according to cultivars in the Borgou district (Benin, 2006 mango season).

| Mango cultivar | Minimum price | | | Maximum price | | | |
|---|---|---|---|---|---|---|---|
| | Unit price | 1 kg | Middle of mango season | Unit price | 1 kg | Start of mango season | End of mango season |
| Gouverneur | 10 | 40 | 13 Apr. – 30 Apr. | 25 | 100 | 28 Mar. – 12 Apr. | – |
| Eldon | 10 | 30 | 18 Apr. – 15 May | 25 | 70 | 03 Apr. – 17 Apr. | – |
| Dabshar | 10 | 20 | 01 May – 29 May | 20 | 40 | 17 Apr. – 30 Apr. | – |
| Kent | 10 | 20 | 01 May – 29 May | 25 | 50 | 17 Apr. – 30 Apr. | 30 May – 19 June |
| Smith | 10 | 20 | 10 May – 05 June | 25 | 55 | – | 06 June – 25 June |
| Keitt | 10 | 25 | 15 May – 19 June | 25 | 60 | – | 20 June – 05 July |
| Brooks | 10 | 20 | 29 May – 25 June | 25 | 45 | – | 26 June – 15 July |

At the start of the crop year, the average weighted price is at its maximum because supply is low and demand is high (*table V*). This maximum price reaches between 50 FCFA (Kent) and 100 FCFA (Gouverneur). At the end of the crop year, mangos fetch between 45 FCFA (Brooks) and 60 FCFA (Keitt). Using these two extremes, we were finally able to calculate an average weighted price from the two preceding figures.

Further studies are necessary if mango market price fluctuations are to be more thoroughly understood. These studies should be undertaken on two consecutive crop years so that market price variations can be estimated according to alternate-year mango production levels. In addition, it would be worthwhile extending these studies to other mango-producing regions in Benin, such as Atacora. We observed harvesting period differences from two to three weeks for the same cultivar grown in Borgou and in this northern district of Benin. For example, price per kg (or per basket) for the Kent cultivar multiplies by three or even four during the month of July in Atacora, as long as the fruit is sold along the main highway (Natitingou-Tanguieta).

## 3.6. Crop loss due to fruit flies

### 3.6.1. Production loss

Using their ovipositor, fruit flies puncture the fruit for two reasons: for food (infrequent) and for egg-laying (very frequent), but which is unfortunately very detrimental to fruit production. We focused on the latter.

According to our results (*table VI*), as also observed in Guinea, fruit flies can lay eggs in young fruits from (4 to 10) weeks after fruit setting. We observed that there are significantly more pupae per kg on young fruits on the soil than on the tree ($F_{1,\ 26}$ = 35.82; $P < 0.001$). We obtained significantly more *B. invadens* in young mangos in March than in February ($F_{1,\ 26}$ = 10.52; $P < 0.003$) but no significant difference appeared for fruit position ($F_{1,\ 26}$ = 0.10; $P < 0.753$). For the other fly species, we also obtained significantly more *C. cosyra* in young mangos in March than in February ($F_{1,\ 26}$ = 77.09; $P < 0.001$) and also a difference for fruit position: fruits laid on the ground are significantly more exploited ($F_{1,\ 26}$ = 63.16; $P < 0.001$) by this native species. This, of course, leads to the logical conclusion that early control methods before the mango season will be very worthwhile. On the other hand, the collection and destruction of fallen fruits under the mango trees needs to be given sufficient attention.

However, most egg-laying in mangos takes place at the pre-ripening and ripening stages, both for tephritidae of the *Ceratitis* genus and the *Bactrocera* genus. Egg-laying is sometimes difficult to detect the same day, and is revealed by at least one drop of sap or, at the most, a small translucent flow of sap (*figure 1*) emanating from the bite. On the other hand, several days after egg-laying either by *Ceratitis* (*figure 1*) or by

**Table VI.**
Comparative analysis of early stages of mango fruits being infested by Tephritidae in Benin (Borgou) (*B.* = *Bactrocera*; *C.* = *Cosyra*).

| Month | Position | Fruit size (mm) | Pupae per kg | *B. invadens* counts | *C. cosyra* counts | Average weight per fruit |
|---|---|---|---|---|---|---|
| February | on tree | 13.52 ± 1.38 a | 0.45 ± 0.10 a | 0.00 | 0.35 ± 0.12 a | 13.68 ± 2.33 a |
| | on soil | 16.65 ± 1.38 b | 1.21 ± 0.10 b | 0.23 ± 0.15 | 1.36 ± 0.12 b | 20.93 ± 2.33 b |
| | average | 15.09 ± 0.97 x | 0.83 ± 0.07 x | 0.11 ± 0.10 x | 0.86 ± 0.08 x | 17.31 ± 1.64 x |
| March | on tree | 18.43 ± 1.48 c | 1.41 ± 0.11 c | 0.45 ± 0.16 c | 1.46 ± 0.12 c | 20.74 ± 2.49 c |
| | on soil | 26.31 ± 1.48 d | 1.95 ± 0.11 d | 0.79 ± 0.16 c | 2.43 ± 0.12 d | 40.25 ± 2.49 d |
| | average | 22.37 ± 1.04 y | 1.68 ± 0.07 y | 0.62 ± 0.11 y | 1.95 ± 0.09 y | 30.5 ± 1.76 y |

Means in the same column followed by the same letter are not significantly different. Comparison was made for months and for position within months.

*Bactrocera* (*figure 1*), black traces can be found that are easier to see, especially on the yellowish skins of certain cultivars. One sole bite can cause considerable internal damage, leaving larvae tunnels and very visible dejections. A number of pathogens then can also quicken the damage to the fruit.

Differences in yield loss have been observed for each cultivar; they are due to several intrinsic and extrinsic factors. Specific intrinsic factors for each cultivar are: (i) the kairomonal complex (very attractive smells), (ii) fruit color, which depends on ripening stage, and (iii) ripening date (early cultivars, seasonal cultivars, late cultivars). Thus, late, yellow cultivars with thin skins (such as Alphonse and Brooks) are more attractive than early, green cultivars with thicker skins (such as Gouverneur) [7, 13]. Quantitative studies on the effects of fruit color, size and weight are planned for the forthcoming crop years. Extrinsic factors also affect yield loss, such as the presence or absence of weaver ants, *Oecophylla longinoda*, on the mango trees. This is because ant abundance is negatively correlated to fruit fly damage as demonstrated in Benin [14].

The progress of damage to the various cultivars, assessed every 2 weeks for the 2006 crop year, reveals that over 50% of fruit fly damage has occurred by around mid-May for five cultivars out of the seven studied (*figure 2*). Taking all cultivars together, losses stand at 17% in early April and exceed 70% at mid-June. More generally, populations of fruit fly are most abundant during the peak of ripening time of mangos as recorded for the genus *Anastrepha* in Central America [15] and South America [16], for the genus *Bactrocera* in India [17] and in the Pacific ocean [18] as well.

About the method used, we believe that this gathering of mangos per cultivar, per site and per date is not completely satisfying but it was the only one to be carried out in this case. The best method that we have already developed is the storing of fruits in individual containers, but for more than 10 000 collected mangos it was not possible to separate each fruit in this case. At each mango sampling we noticed the presence or not of oviposition marks. To summarize, we can say that these visible marks (oviposition punctures) were recorded on sampled mangos as a backup to a very accurate record of emerged pupae according to Stonehouse *et al.* [19].

### 3.6.2. Economic loss

Losses attributed to tephritidae varied between 0.34 t and 6.5 t per ha according to the cultivar (*table VII*), resulting in major income loss for the five mango orchards, which cover 58 ha overall. Yield losses per cultivar and per ha are considerable in the light of average weighted prices (*table VII*). For example, for cultivars grown for export to Europe, the economic loss

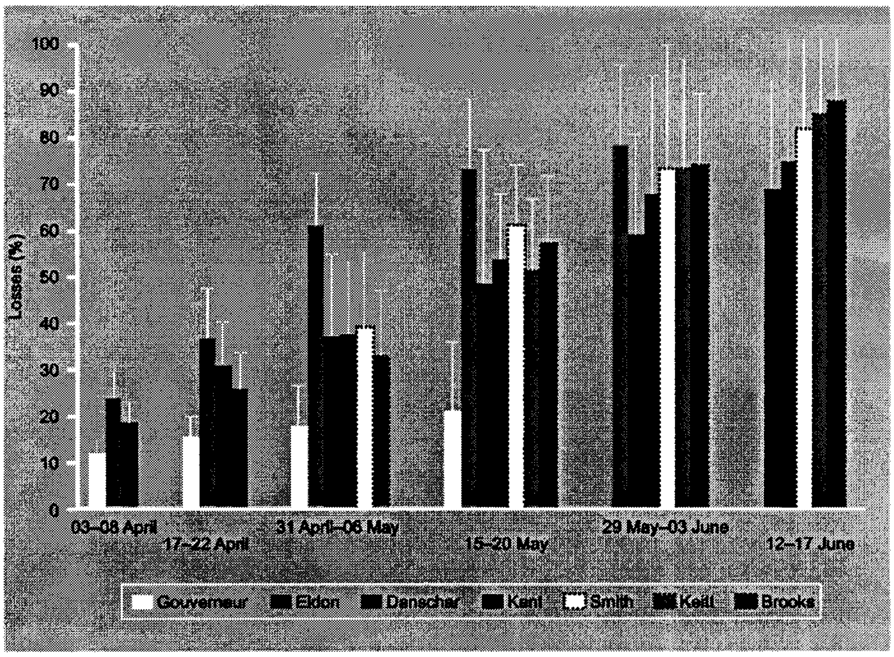


**Figure 2.**
Average damage caused by Tephritidae to seven different cultivars during the mango season of 2006 in the North of Parakou (Benin, Department of Borgou).

**Table VII.**
Losses caused by fruit flies, and average sale prices for fruits of the seven main cultivars found in five orchards studied in the Borgou district (Benin, 2006 crop year).

| Mango cultivar | Average yield ($t \cdot ha^{-1}$) | Average damage per cultivar and per tree (%) | Yield losses ($t \cdot ha^{-1}$) | Theoretical average sale price without fruit flies ($FCFA \cdot t^{-1}$) | Financial loss due to fruit flies (using average price) ($FCFA \cdot t^{-1}$) | Financial loss of yield (using average price) ($FCFA \cdot ha^{-1}$) |
|---|---|---|---|---|---|---|
| Gouverneur | 1.803 | 19 | 0.342 | 70 000 | 13 300 | 23 940 |
| Eldon | 8.864 | 60 | 5.318 | 50 000 | 30 000 | 265 900 |
| Dabshar | 2.883 | 44 | 1.268 | 30 000 | 13 200 | 38 040 |
| Kent | 5.928 | 45 | 2.667 | 35 000 | 15 750 | 93 345 |
| Smith | 9.102 | 49 | 4.459 | 38 000 | 18 620 | 169 442 |
| Keitt | 6.091 | 53 | 3.228 | 43 000 | 22 790 | 138 804 |
| Brooks | 10.407 | 63 | 6.556 | 33 000 | 20 790 | 216 348 |

per ha calculated on average prices is 93 345 FCFA (Kent) and 138 804 FCFA (Keitt).

Differences in loss of income per ha for the various cultivars reflect the sale price per kg of mangos. This price is calculated in kg because the fruit is usually sold by the basket or the bowl by the gatherers.

### 3.7. Plant diversity in monitored orchards

Numerous types of fruit tree affect the fluctuations in fruit fly populations that colonize the mango trees in the Borgou district. These trees contribute not only to the multiplication of the species, since they are alternative hosts to the mango tree, but the tephritidae or leks can gather there at certain times of the day.

### 3.7.1. Cultivated fruit trees

The guava tree *(Psidium guajava)* is a primary host for *B. invadens*, as are the plum bush tree (*Spondias mombin)* and the crab apple tree *(Irvingia gabonensis).* Annona trees (*Annona* sp.) and citrus fruit trees (*Citrus* spp.) are secondary hosts in the Borgou district although Citrus are primary hosts in southern Benin.

The cashew nut tree (*Anacardium occidentale*) is an important primary host for *C. cosyra*, allowing these populations to proliferate between mid-January and mid-March, *i.e.,* just before the fructification period for early mango cultivars. This is particularly important because cashew nut orchards are often situated close to mango orchards. In this way, this can trigger quick infestation on mango trees in February and March, before the mango season.

Furthermore, *C. cosyra* leks (usually female leks) can be found on certain mangos that have fallen from the trees at the end of the day, and also on *Sarcocephalus latifolius*.

### 3.7.2. Wild fruit trees

The shea-butter tree (*Vitellaria paradoxa*) is a wild primary host for *B. invadens*, while marula plum (*Sclerocarya birrea*) and *Diospyros montana* are secondary hosts. The African peach tree (*Sarcocephalus latifolius*), *Cordyla pinnata* and *Sclerocarya birrea* are the three wild primary hosts for *C. cosyra*; they are commonly found in the dry savannah regions of Borgou.

We found about 40 hosts, cultivated and wild as well, in Benin for the polyphagous *B. invadens*. We have two expectations for our ongoing applied research:

– First, this very large host range needs actually to be taken into account for fruit fly control on the production basin level, when an integrated pest control program targeting the mango fruit fly is being planned and implemented.

– These other hosts could be used as part of a new fruit fly control approach. The objective of this new approach should be to optimize ecological mechanisms of management of tephritid populations (push-pull with mimetic molecules, etc.) linked and enhanced with supra-specific plant diversity including wild hosts.

## 4. Conclusion

The mango production sector suffers heavy economic losses due to damage caused by fruit flies, which are in Benin the main menace, considerably decreasing mango yield compared with other pests (scale insects, termites, etc.). The damage on mangos has been seriously increased with the arrival from Asia of the new invasive fruit fly of the genus *Bactrocera*. Only a widespread environment- and consumer-friendly integrated pest management program (IPM package) targeting mango fruit flies can reduce the populations of these destructive pests and can keep them under the Economic Injury Level (EIL). It is to be hoped that classical biological pest control of the new invasive species, *B. invadens*, will be as successful with natural enemies as the previous IITA campaign against the famous mango mealy bug, *Rastrococcus invadens* [11], with exotic parasitoids.

These preliminary observations concerning the mango tree in Benin are connected with several other studies undertaken on fruit fly ecology and control methods. The mango production sector is threatened by the same pests, on the national scale (Benin) and on the regional scale (West Africa). Thus, it makes sense to develop a regional control program against mango fruit flies in all West Africa and not only in Benin. It is important to validate pest control methods as soon as possible, and to deliver them to extension services. In this way, we intend to define the EIL principle in a forthcoming article that will focus on these two main species of mango fruit fly, *B. invadens* and *C. cosyra*, with the same mango cultivars studied in this first article.

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## El mango en centro y el norte de Benín: inventario de los cultivares, estimación de los rendimientos, fases afectadas y pérdidas causadas por las moscas de las frutas (Diptera Tephritidae).

**Resumen — Introducción**. El mango ocupa un lugar particularmente importante en la economía rural de las zonas Centrales y septentrionales del Benín. Durante el final de la estación seca, el mango constituye un aporte nutricional fundamental debido a su fuerte contenido en nutrientes. Sin embargo en Benín los productores de mangos se enfrentan a dos obstáculos estrechamente relacionados uno con otro: falta de calidad del fruto causado por las plagas e insuficiencia de las técnicas adecuadas de 'post-cosecha'. En la zona sudano-beninesa las moscas de las frutas (Diptera Tephritidae) forman el obstáculo de mayor responsabilidad de las considerables pérdidas de producción. **Material y métodos**. Se realizaron en 7000 frutos alrededor de Parakou, durante los años 2005 y 2006, tanto el inventario de los cultivares presentes en Mali como las estimaciones de los rendimientos de los principales cultivares de mango (Gouverneur, Eldon, Dabshar, Kent, Smith, Keitt, Brooks). Se llevaron a cabo muestreos de 3000 frutos pequeños (de 13 mm a 26 mm) en el 2006 con el fin de averiguar cúales eran las fases más precoces para ser atacadas. Asimismo se llevaron a cabo en 2006 unas estimaciones de las pérdidas a nivel de las fases de pre-madurez y de madurez en 10 500 frutos. **Resultados y discusión**. Identificamos 29 cultivares en el departamento de Borgou en donde se concentra cerca del 75% de los vergeles de mangos del Benín. La mayoría de ellos pertenece a un sistema de producción de 'tipo cosecha'. El cultivar precoz Gouverneur (1,8 $t{\cdot}ha^{-1}$) tuvo el rendimiento más flojo y el cultivar tardío Brooks tuvo el rendimiento más elevado (10,4 $t{\cdot}ha^{-1}$). Los frutos pequeños inmaduros permitieron el desarrollo completo de *C. cosyra* y de *B. invadens* durante los meses de febrero y marzo, es decir bastante antes de la campaña del mango; lo que podría tener aplicaciones a nivel de la lucha. Para las fases de pre-madurez y de madurez de los frutos, las medias de las pérdidas causadas por los Tephritidae variaron de 0,34 $t{\cdot}ha^{-1}$ a 6,5 $t{\cdot}ha^{-1}$ según el cultivar; y, ocasionaron una pérdida de ingreso considerable para los pequeños plantadores. Teniendo en cuenta la media de todos los cultivares, las pérdidas alcanzan el 17% a principios de abril y sobrepasan el 70% a mediados de junio. Más del 50% de las pérdidas se registraron a mitad de la campaña del mango. El cv. de temporada Eldon y los cv. tardíos (Keitt, Brooks) fueron los más infestados. **Conclusión.** Las dos mayores especies de Tephritidae de interés económico para el mango en el norte de Benín son *B. invadens* y *C. cosyra*. Este estudio preliminar debería servir de base para el cálculo del umbral económico de nocividad de estos Tephritidae del mango en un próximo artículo.

**Benin / *Mangifera indica* / etapas de desarrollo de la planta / Tephritidae / *Bactrocera invadens* / *Ceratitis cosyra* / variedades / rendimiento / picaduras de insectos / pérdidas de la cosecha**