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Dramatic Fruit Fall of Peach Palm in Subsistence Agriculture in Colombia: Epidemiology, Cause and Control

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Introduction

The peach palm (chontaduro, pejibaye, jei[1]) *Bactris gasipaes* Kunth. (Arecaceae) is native of the humid lowlands of the neotropics and was domesticated already by the Amerindians 2000 years ago (PATIÑO, 2002). Cultivation in the Americas is from Costa Rica to Northern Peru on the Pacific coast, and on the Atlantic coast from Honduras to Brazil. In Colombia besides the cultivated western landrace of *B. gassipaes*, also the type II of the wild species is present in the northeast of the country (GRAEFE et al., 2013). *B. gasipaes* is cultivated for its starchy, valuable oils (omega-3, omega-6), protein and vitamin rich fruits and for its palm heart commercialised as 'palmito'. The relative high price of the fruit, the long storage time and relative easy transportation make it an ideal cash crop for the humid tropics. This applies specially to the riverside settlements of the Central Pacific coast of Colombia with its high rainfall and long transportation routes to populated centres of Buenaventura and Cali.
In the riversides of the Central Pacific coast *B. gasipaes* can produce over 10 inflorescences during the year, which following an insect aided pollination produce after 4 month up to 3 fruit mature bunches with a maximum of over 100 fruits each. The palm forms multi stemmed elevated and inundation tolerant hills with stems reaching up to 20 m in height. The stems are covered with up to 4 cm long spines protecting the fruits from climbing rats and making climbing impossible, so that harvesting of the fruit bunches has to be achieved with bamboo poles. Flowering of *B. gasipaes* on the Central Pacific coast of Colombia is twice a year and harvests periods are from February to April and May to July. The peach palm tolerates some overhead shade, low luminosity and short periodical inundations present at the riverside settlements (veredas) of the Central Pacific coast and makes it ideal for agro-forestry which includes on the same site forest trees such as mahogany (*Cedrela* sp.), plantation crops such as guava (guayaba) (*Psidium guajava* L.), cocoa (*Theobroma cacao* and *T. bicolor*), borojó (*Borojoa patinoi*), plantains (*Musa* AAB, ABB) and bananas (*Musa* AAA), and the flooding tolerant tuber taro

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[1] In the language of the native tribe Embera at the vereda Peña de Tigre on the river Gangüi which discharges into the river Saija.

(papa china) *Colocasia esculenta*. The only serious drawback in this region is an increasing premature abscission (shedding) of peach palms, causing an appreciable reduction of the cash income of the mostly on subsistence agro-forestry living inhabitants.

The inhabitants of the Central Pacific Coast of Colombia attribute the start of the decay of peach palm fruit production to the earthquake of 1979 causing a prolonged inundation of the lower, medium and even high zones of the rivers, with intrusion of salt water up to the medium zone (LEHMANN-DANZINGER 1989a). Studying the ecology of peach palms on the Pacific Coast of Colombia PAVA, CASTILLO AND GONZALES (1981) found a black weevil of 4 mm length in dropped fruits which they identified as close to the genus Geraeus. Later on, in the early 1980 decade, an increased premature fruit drop of peach palms was observed in the lower zone of the Calima River (bajo Calima) north of Buenaventura. Finally as early as 1984-85 fruit shedding on peach palms was observed in the south of the Central Pacific coast at the river Bubuey according to inhabitants of the vereda Trinidad (table-2).
Finding the causes of the fruits fall of peach palm and developing a method to avoid the losses is therefore the aim of the present extended abstract.

Material and Methods

Observations, data from assessments, setup and results of trials, and origin of samples and photographs were recorded in chronological order in a field diary. All assessed peach palms and otherwise examined plants received a code also used for the trials, samples including trapped insects, and for photographs. An example of a code is 'Bg92/19' for a peach palm from which insects were trapped from the inflorescence and samples taken from the inflorescence (figure-3). The code 'Bg' stands for *Bactris gasipaes*, '92' for the year 1992 and '19' for the ninetieth peach palm sampled in 1992. The stored insects of the inflorescence from palm Bg92/19 received the same code on the respective identification labels. The field diary shows that the sample was taken from an inflorescence opened on the same day on 10 m high peach palm (height of the inflorescence) at 15 hours (3 p.m.) on the 18th of August 1992 at the vereda Pisare I of Boca del Patia, belonging to the river Saija (table- 2).

The degree of fruit fall on bunches of peach palms at different sites was evaluated visually using the grades of table-1.

Table 1: Scale for grading of fruit loss of fruit bunches of *Bactris gasipaes*, adapted to the visual evaluation capacity of the human eye, which is not able to differentiate the grades between 30% and 70% in a consistent manner.

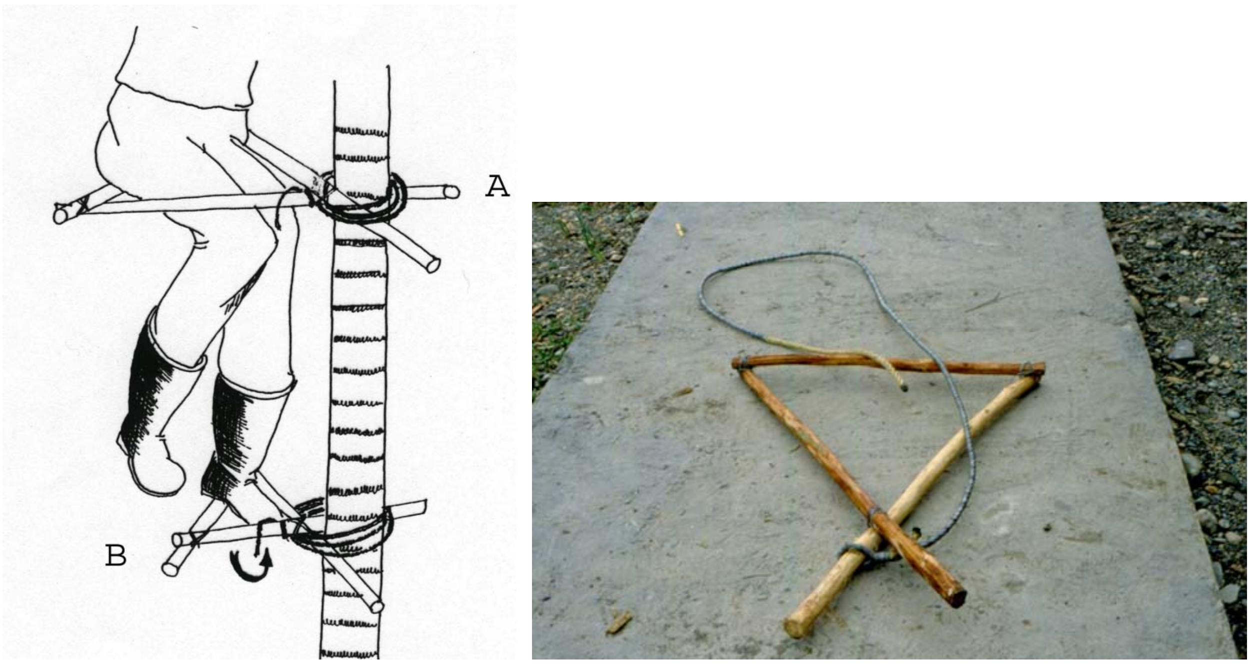
Grade	Degree of fruit shedding
1	<1% or no fruit loss
2	1% to 30%
3	31% to 70%
4	71% to 95%
5	96% to 100%

Improved scaffold for climbing peach palms

A scaffold for climbing peach palms with spines on the stem was improved from a local scaffold with two triangles called 'marota' (LEHMANN-DANZINGER 1992, 1993, 2004). The improved marota scaffold consists of two triangles, a larger upper one (figure-1b) and smaller lower one attached below the upper triangle on the stem (figure-1aB). The 2 triangles are loosely connected to each other by a rope (1/4''and 1.80 m long). Each of the triangles is attached to the stem of the palm by winding a rope (1/2'' diameter and 3.5 m long) around the stem in a way that the triangle can be pushed up the stem when positioned horizontally or in an upward angle. When the triangle is inclined downwards, then the ropes stretches fixing the triangle firmly to the stem. When moving upwards the climber stands on the lower triangle inclining it downwards and then pushes the upper triangle in an upward angle, hereby loosening the rope on the stem and then moves the triangle upwards. After this he (or she) slips up to upper triangle and sits on it (figure-1aA), which inclines the triangle downwards and stretches the rope hereby fixing the triangle firmly to the stem. In a next move the climber hauls the lower triangle up with his feet (figure-1aB) and then changes from sitting on the upper triangle to standing on the lower triangle. Then the operation is repeated, hereby the marota scaffold and the climber move upwards on the stem.

The rope is protected from abrasion by the needles of the stem by wrapping the stretch of the rope attached to stem with a galvanized wire of 2-3 mm diameter (figure-1b).

When the climber has reached the inflorescence diverse objects (insect net, insecticide sprayer) can be hauled up and lowered down (fruit bunches) the palm with a previously attached long rope to the marota scaffolding. Most of the authors of the present extended abstract had been trained in producing the marota scaffold and climbing with it the peach palm. The 1st author used this method to assess the insects on inflorescences and fruits and for testing and developing methods on site to protect the fruits from the voracious weevils. Climbing the palms was essential for the trials of control of the fruit damaging weevils described in the section 'Results and Discussion' and for harvesting fruit bunches from peach palms exceeding 6 metres (m) of height.



a b

Figure-1: Marota scaffold for climbing the peach palm

a: Attachment of the triangles A and B to stem and hauling up smaller lower triangle with a foot while sitting on the upper triangle A.

b: Upper triangle with the attached and partially protected rope by a wrapped around wire. (Photo #19920516)

Results and Discussion

Description of the study area

The area of the assessment lies in the Central Pacific coastal zone of Colombia starting at the Cape (Cabo) Corrientes north of Buenaventura and extends southwards up to the river Bubuey, north of the river Timbiquí. The adjoining South Pacific Coastal zone reaches from the river Timbiquí in the north to the border of Colombia with Ecuador in the south. The Central Pacific coastal zone includes the administrative departments of “Valle del Cauca” and “Cauca”. The area of the present study comprises 6 rivers, starting in the north with the river Cajambre (south of Buenaventura) and ending in south at the river Bubuey (table-2). The area covers a coastline of approximately 2,500 Km with alluvial soils and dominated on the seaside by dense mangrove forests.

The climate of the zone is tropical humid to per-humid with a dry period from January to March followed by a rainy season from May to June, a dry spell in July, and a long main rainy season from August to December. The amount of rainfall in the dry season changes in the course of the years, so that in some years the dry season can be very rainy and not dry. Rainfall is on average 5,262 mm $year^{-1}$ in the estuaries and increases up 18,648 mm $year^{-1}$ at the river heads.

Based on the vegetation, conformation of the terrain and use of the soil, the rivers of the study area can be divided up in a low, medium and high zone (table-2). The low zone comprises the coastal plain with dense mangrove forests, estuaries, channels (esteros), and lagoons (bocanas) formed by the discharge of the rivers into the Pacific. The channels (figure-2) running parallel to the coast are used for navigation from one river to another and for longer journeys to the ports of Buenaventura and Timbiquí. Settlements (veredas) in this zone consist of houses built on high stilts at the borders of the channels. The low zone is under the influence of tides and most of the plains are flooded with high water. The tides cause also an increase of the water level in the rivers of the medium zones, which allows navigation of larger boats with high water. High water lead to flooding increased by high rainfall in the riverside agro-forest plots. However, severe flooding occurs when spring tides are accompanied by high rainfall. The main source of income in the low zone is fishery in the seaward mangrove section and coconut production in the landward mangrove section with stabilised soils. Peach palms grow on more stable and less flooded higher terrain of the lower zone.

Figure-2: Channel in the mangrove forest in the low zone of the rivers. The dominant mangrove tree is here the red mangrove *Rhizophora mangle* with characteristic stilt roots.

Photo #19922526

The medium zone is not affected by salt water incursions and the 100 m to 500 m wide flat riversides are used for agro-forestry. The riverside plains are limited by 100-250 m high hills. The main settlements of the rivers are here in the medium zone. The high zone at the river heads is dominated by up to 500m high mountains of tertiary origin, narrow flat riversides, and difficult navigable rivers. The main activity is here mining of gold and silver and to lower extent agro-forestry. However, peach palms are also frequent in this zone.

Table-2: Rivers and riverside settlements (veredas) or districts comprising the study- area at the Central Pacific Coast of Colombia.

River name	Department Colombia approx. length	Latitude and longitude at river mouth (Pacific ocean)	Veredas (settlements) along the river starting at the mouth discharging in the Pacific (low zone) and ending in the high zone at the foothills of the Cordillera Occidental mountain range
Cajambre	Valle del Cauca 24 km up to Barco	3°31’10.92”N 77°17’43.85W	Low zone: El Pital, Punta Bonita, Corozal, Aserrío, La Fragua,Vigía, Silva, El Calve, El Chorro. Medium zone: Silva, S. Vicente, S. Isidro, Cajambre, Cunapa, La Ventura. High zone: Sta. Rosa, Barco.
Yurumangui	Valle del Cauca	3°22’46”N 77°21’52”W	Low zone: El Firme, Barranco, Dos Penas, Aserrío La Primavera, Veneral, Papayo. Medium zone: Aserrío El Carmen, La Jagua, S. Miguel, Boca del Yuca, S. Antonio, El Aguila, S. Gerónimo, S. José. High zone: S. Antoñito, Las Juntas.
Naya	Valle del Cauca 117 km	3°18’02”N 77°26’39”W	Low zone: Chamuscado, Sta. Cruz, El Ají, S.Fernando, La Vuelta, S.Pedro, S. Pedro Naya. Medium zone: Pto.Merizalde, La Playita, El Trueno, El Pastico, Cabiru, Sagrada Familia, Sta. Maria, S. Francisco de Naya. High zone: San Lorenzo, La Concepción, Cascajito.
Micay	Cauca 177km 90 km from Lopez de Micay to Bocana (river mouth) Micay	3°05’00”N 77°32’00”W	Low zone: Bocana Micay, Punta Bodega, Punta Ají, Boca Candelaria, Boca Grande, el Coco, Isla el Sande, El Trapiche, Noanamito. Medium zone: S. Pablo, La Laguna, Sta. Ana, Limones, Guayabal, Río Viejo, La Rotura, Bujío, Sanmaina, La Ensenada, Iguana, Zaragoza, El Arenal, Barranco, Casa Viejas, S. Joaquin, Calle Larga, S. Isidro. High zone: Antonio Chuare, Lopez de Micay, Pto. Sergio, Alto Chuare, S. Antonio.
Saija	Cauca 60 km	3°56’27”N 77°38’29”W	Low zone: S. Franzisco, Los Brazos, Sta.Barbara, S. Agustin. Medium zone: Pto. Saija, La Pena, Estero Taganga, Sta. Rosa, La Simona, La Viuda, La Vaquería, S. Francisco, Boca de Gangüi, Peña de Tigre. High zone: Boca del Patia, Pisare, Angostura, S. Agostin, Tulua, Sta.Rosa del Saija.
Bubuey	Cauca	2° 50' 59" N 77° 41' 45" W	Low zone: Chacón Mediun zone: Almorzadero, La Trinidad

Underlined name = Administrative Centre, S. = San, Sta. = Santa, Pto. = Puerto

A first assessment (LEHMANN-DANZINGER, 1989) of peach palms in the southward rivers Naya, Micay and Saija showed different degrees of fruit fall in the 3 rivers and also in the lower, medium and high river zones of the same river. Premature fruit fall at different stages of fruit development was in some cases accompanied by disease symptoms consisting of yellowing and dieback of fronds and death of whole peach palms.
About 80% of fruits of peach palms recollected from the soil and kept at room temperature, started to rot after 3 days and showed tunnels starting at the surface and extending into the fruit, obviously made by white and by creamy coloured small apodous (legless) larvae of 3.8 to 4.8 mm in length within the tunnels. Both larvae had a brown head capsule with chewing mandibles which is typical for the apodous weevil larvae (Coleoptera: Curculionidae). The question arising now was whether the weevils had been laying the eggs on the fruits still attached to the raceme on the palm or if oviposition was on fruits on the soil were also larvae could have entered the fruits from the soil or material thereon. Unfortunately it was not possible to examine the fruits on the racemes of peach palms, because climbing the up to 20 m high palms was not possible due to 5 cm long hard spines covering the stems. Felling of palms with developing fruit bunches could have answered the question. However, there was a fierce opposition to felling of palms from part of the owners, which is understandable because the palms represent in most cases the only source of cash income.
On a further assessment (LEHMANN-DANZINGER, 1992) it was possible to examine the inflorescences and fruits on the racemes still attached to the palms with the aid of an insect net with extensible handle and a scaffolding for climbing palms developed on site (see section ‘Material and Methods’).

Insects on fruit of the fruit bunch and inflorescences

Two small weevils were always present on all examined fruit bunches: a small on average 2 to 3.2 mm long black weevil and a grey rapid moving weevil with an average length of 2 mm. Fruits sampled on the palms from younger and older bunches, showed damage by feeding of larvae comparable to the described above for fruits drooped to the ground. Collected damaged fruits were incubated in Styrofoam boxes covered with a 0.5 mm mesh screen and additionally placing a layer of soil (sampled from under peach palms) on the bottom of the boxes. Incubation was at room temperature. The larvae emerging from the fruits burrowed immediately into the soil and pupated without forming a case (exarate pupa) in small caves of the soil lined out with slime. Approximately two weeks later both of the above described weevils emerged from the soil. In several experiments the soil in the rearing boxes dried out and the pupae changed to a diapause state for several weeks, and in some cases even for up to 3 months, and emerged only when the soil remained humid for about a week. The emerged weevils in the boxes identified with aid of 10 fold magnifying lens seemed identical to the weevils trapped on the fruit bunch and identified below.
The grey weevil was identified by Charles W. O’Brien of the Center for Biological Control at the Florida A&M University in Tallahassee, Florida U.S.A., as ***Parisoschoenus sp.,*** Coleoptera: Curculionidae, Baridinae, Madarini.
The black weevil resisted all effort for identification for several years and was finally identified thanks to the perseverance our friend Charles O’Brien as a new species belonging also to a new genus (O’BRIEN 2000): ***Palmelampius heinrichi*** O’Brien sp. n., Coleoptera: Curculionidae, Baridinae, subtribe Zygobaridina.

Insects were trapped from 1 to 2 day old inflorescences with open male (staminate) flowers to determine the presence of the 2 weevils. The result of the trapping was a surprise, because of the enormous amount and the diversity of insects present on the inflorescences from aperture until abscission of the staminate flowers. Figure-3 gives an impression of the amount of insects present in the morning following aperture of the inflorescence in late evening of the past day. Obviously the inflorescences of peach palms are visited already in the twilight and the night by an increasing numbers pollinating insects. Most of the insect species on the 1st day inflorescence belong to a red-brown *Phyllotrox* weevil, shown in figure-3 crawling along the inner surface of the plastic bag. A summary of the most important insects on 1-2 old inflorescences, before abscission of the male flowers, is given in table-3.

Figure-3: Insects recollected with an insect at 6 hours following the aperture of the inflorescence of *Bactris gasipaes* at the vereda Pisare near Boca del Patia (river Saija).
B. gasipaes palm Bg92/19 of 10 m height (Photo19922912).

Table-3: Insects on inflorescences of *Bactris gasipaes* during the 1st and 2nd day of aperture

Code #	Description and identification code	Taxonomic classification
1	Black small weevil (picudo negro pequeño) (Cnp)	*Palmelampius heinrichi* O'Brien sp. n., Coleoptera: Curculionidae, Baridinae. Peach palm fruit damaging!
2	Tiny rapid grey weevil (picudo gris rápido) (Cgr)	*Parisoschoenus* sp., Coleoptera: Curculionidae, Baridinae, Madarini. Peach palm fruit damaging!
3	Tiny red-brown weevil (picudo café diminuto) (Ccd)	*Phyllotrox* sp., Coleoptera: Curculionidae, Erhininae, Derelomini up to 50,000 weevils on one inflorescence
4	Small tan weevil (Ccm)	Coleoptera: Nitidulidae. Up to 5,000 per inflorescence
5	Very small beetles with short elytra (Lat)	Coleoptera: Staphylinidae, Aleocharinae
6	Medium sized tan beetles (Cyc)	*Cyclocephala* sp., Coleoptera: Scarabeidae, Dynastinae, Cyclocephalini
7	Fruit flies (moscas de la fruta), very small flies with red eyes (Dro)	*Drosophila* sp., Diptera: Drosophilidae
8	Small bees (abejitas) (Tri)	*Trigona* sp. Hymenoptera: Apidae.

Table-3 shows that besides the 2 fruit damaging weevils present in low numbers ranging from 4 to 6, a high diversity of pollinating insects in great numbers is present on the inflorescences before abscission of the male flowers, confirming the finding of LISTABARTH, C. (1992) in the Amazon Basin. This finding shows that a strategy for control of the damaging weevils should avoid killing the pollinating insects, which in the case of *Phyllotrox* seem to be rather specific for palms of the genus *Bactris* (LISTABARTH, 1996). To accomplish such a goal, control of the 2 weevils responsible for the fruit shedding of peach palms should start only after the abscission of the male flowers, which takes place on the 2nd to 3rd day following aperture of the inflorescence.

Numerous trials for control the pest weevils *Palmelampius heinrichi* and *Parisoschoenus* showed consistently a good control for the following methods, based on protecting the new fruit bunch from attack of the weevils, after abscission of the male flowers:

A) Covering the fruit bunch with a 0.5 mm mesh Teflon net bag and previous killing of the weevils present on the bunch with an insecticide containing either one of the following active ingredients (a.i) phosphamidon, clorpyrifos or carbofuran (figure-5).
B) Covering the fruit bunch with a 0.5 mm mesh Teflon net bag and eliminating before the weevils present by shaking the bunch. Several trials showed that when shaking the bunch the weevils are overcome by an innate reflex which comply them to fall down immediately achieving hereby a weevil free fruit bunch.
C) Covering the fruit bunch with a clorpyrifos impregnated and on the lower side open plastic bag. This bag is used by banana growers to protect the banana bunches against fruit scarring beetles and gives protection for up to 3 months. If maturing takes longer and weevil population is high, then the nearly ripe bunch is subject to a strong weevil attack.

The effect of the described methods on protecting the second smaller harvest of the year from the weevils is shown on figure-4.

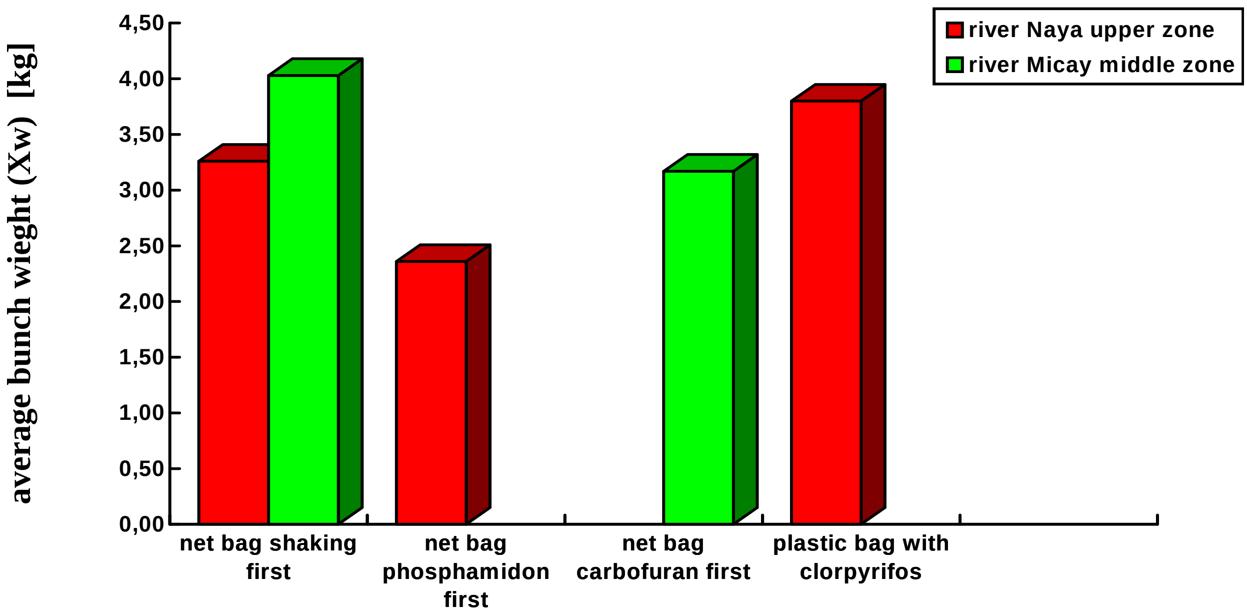


Figure-4: Effect of protecting peach palm fruits with a net bag and Dursban impregnated plastic bag against the small black weevil (*Palmelampius heinrichi*) and the tiny grey rapid weevil (*Parisoschoenus* sp.) on weight of fruit bunch. Unprotected fruit bunches had no fruit.

(Fig-4 continued) X_W mean weight. Net bags of nylon with 0.5 mm mesh.
Manual treatment before bagging by shaking the inflorescence vigorously for about 3 minutes.
Chemical treatment before bagging by spraying of fruit bunch with 4ml/l Dimecron (a.i. phosphamidon) or 4 ml/l Curater (a.i. carbofuran).
Full chemical control for up to 3 months by bagging the fruit bunch with a plastic bag with 2% Dursban (a.i. clorpyrifos) incorporated into the resin of the bag.

Photo #19936226

Figure-5: Mature fruit bunch of *Bactris gasipaes* from the first harvest in the year, protected with a net bag 4 months ago and killing the present weevils with insecticide before baging. Trial in the vereda San Francisco of the river Naya.
Control bunches are devoid of fruits when not protected.

Photo #19936233

Conclusions and Outlook

The presence of pollinating insects on the inflorescences of *B. gasipaes* are killed, when insecticides are applied to an inflorescence with the male flowers still attached. However, recommendations for control of the weevils in Colombia are often based on applying insecticides or insecticide impregnated plastic bags already on the 1st day following aperture of the inflorescence. The consequence is a massive killing of the peach palm pollinating entomofauna, which in the long run will invariably reduce pollination of peach palms leading to lower yields and causing a severe impact to the biodiversity of the entomofauna of Pacific coast of Colombia.

There seems to be a misunderstanding on the effects of insect impregnated plastic bags in controlling the pest weevils. Some authors recommend a control of the weevils by covering the fruit bunches with blue translucent plastic bags without insecticides. This method was involuntarily tested in our trial, when peach palm owners placed untreated plastic bags over fruit bunches, because they had seen the effect of our insecticide impregnated plastic bags, not

knowing that these had been impregnated with a volatile insecticide. The outcome of using untreated plastic bags was a total damage of the fruits. However, some fruit bunches near the treated plastic bags showed no or a decreased attack in spite of not having been protected. Here an effects of the volatile fungicide spreading from the treated plastic bags to the unprotected bunches is probable.
The methods of control proposed and tested by the authors of the present expanded abstract had a widespread resonance and acceptance by the inhabitants of the Central Pacific coast of Colombia, following the success of the initial control trials and the rapid increase of peach palm fruit yields of the participating Afrocolombian and Embera subsistence farmers of the region. The nowadays propagated methods for controlling the weevils in Colombia are obviously based on our results. However, there was no possibility to continue validating the control methods because of the lack of funds for a further mission and a wider dissemination the results. Another reason impeding further efforts is the increasing violence in the region during the last decade.

A still open question is the origin of *Palmelampius heinrichi*, which obviously invaded relatively late the peach palm plantings of the Pacific Coast of Colombia. Up to now the only known host plant of the weevil is *Bactris gasipaes.* Therefore it seems probable that this weevil has evolved together with wild species of *Bactris* in the Neotropical genetic centre. This means that the weevil should be present on the wild *Bactris* palms, which according to COUVREUR et al (2007) are genetically closely related to the cultivated *Bactris gasipaes* forms.

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