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Stakeholders' perception of weaver ant's effects on mango fruits quality in Benin

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Weaver ant (*Oecophylla longinonda*) used in biological control of pest, is said to improve the organoleptic quality of protected fruits. This study aims at bringing out stakeholders' perception of weaver ants effect on mango quality. A survey was performed in Parakou (Benin), with stakeholders to assess their perception of mango quality and their opinion about weaver ant's effect on mango quality. Then, the taste and the appearance (performed on unwashed and washed fruits) of three categories of mango: Control mango CM (Mango without ants), ants mango without scale insect (AM) and ants mango with scale insects (AMS) were evaluated by 25 panelists. Survey showed that maturity, appearance, size, non-infestation and firmness were the main criteria used by stakeholders to assess mango quality. Differences between protected and non-protected mango were based mainly on taste, appearance and non-infestation (68.8%; 48.4%; 31.3% of respondents, respectively). Most respondents (88.6%), who used taste to differentiate protected mango from non-protected mango, declared that the former is sweeter than the latter. Some respondents (35.5%) negatively pointed out the presence of scale insects and / or ants marks on the peel of protected mango. All respondents stated that protected mango is non-infested by pest. Similarly, sensory test showed that AMS scored the highest grade (4.5) followed by AM (3.9) and CM (2.8) for the taste (for washed fruits), registered the highest score (3.8) ahead AM (3.2) and CM (2.7). This investigation showed that weaver ants improve mango, taste and appearance. Mango quality changes due to the presence of weaver ants should be investigated.

Key words: *Oecophylla longinoda*, biological control, survey, criteria, Parakou, organoleptic quality.

INTRODUCTION

Mango [*Mangifera indica* L (Sapindales: Anarcardiaceae)] is the eighth most produced fruit in the world (UNCTAD, 2016), with a global production raising from more than 43 million tons in 2013 to nearly 46 million tons in 2016 (FAOSTAT, 2018). In Benin, mango is widely consumed and has a nutritional, social and economic importance especially in central and northern rural parts which are the main production areas in the country (Vayssières et al., 2008, 2012).

As for most of crops, mango production has some constraints. Pest attack by fruit flies [*Bactrocera invadens* (Hendel) (Diptera: Tephritidae) and *Ceratitis cosyra*

(Walker) (Diptera:Tephritidae)] is one of the major problems faced by producers in developing countries with limited resources including Benin (Sinzogan et al., 2008; Adandonon et al., 2009). The use of weaver ants [*Oecophyla longinoda* (Latreille) (*Hymenoptera: formicidae*)] as biological control agent, is one of the pest management methods developed in mango orchard (Ouédraogo, 2011; Vayssières et al., 2009; Sinzogan et al., 2008). Biological control by the use of weaver ants in different horticultural systems (cashew, citrus, mango, etc.) has shown its efficiency and economic benefit in many countries (Australia, China, Ghana, Guinea, and Benin) (Peng et al., 1997; Van Mele and Cuc, 2000; Sinzogan et al., 2008; Van Mele et al., 2009; Offenberg and Wiwatwitaya, 2009). There are two species of weaver ants in the world [*Oecophylla smaragdina* (Fabricius) (*Hymenoptera: formicidae*)] living in Asia and [*Oecophylla longinoda* (Latreille) (*Hymenoptera: formicidae*)] native to Africa,) (Hölldobler and Wilson, 1977; Offenberg and Wiwatwitaya, 2009). Weaver ants are dominant and predatory ants, living in colonies (Déguénon, 2009). Its presence on a plant prevents pests attack (fruit flies, various insects, rodents, bats, etc.) of this plant and its fruits (Van Mele et al., 2009; Adandonon et al., 2009). Even though, weaver ants prey on most insects, they guard scale insects (*Pseudococcidae*) as though they were dairy cattle (Hölldobler and Wilson, 1997). Indeed, weaver ants gather and feed on the honeydew (sugary secretion) that scales insects produce (Ledoux, 1949; Van Mele and Cuc, 2007; Van Mele and Cuc, 2008; Dwomoh et al., 2009). These scale insects live on different parts of the host tree (leaf, fruit, bark).

According to different stakeholders, weaver ants are supposed to improve the quality, especially the organoleptic quality of protected fruit (Barzman et al., 1996; Sinzogan et al., 2008; Van Mele et al*.,* 2009; Olotu et al., 2013). Indeed, many statements in relation to a probable quality improvement of fruit protected by the ants are declared by stakeholders. So, the use of weaver ants could present a comparative advantage from efficiency and economic benefit point of view. This study aims at bringing out Benin stakeholders' view of weaver ants effect on mango fruits compared to their sensory quality.

MATERIALS AND METHODS

To fulfil the study aims, the main quality criteria, used by the stakeholders when choosing a mango, were recorded. Then, their knowledge of weaver ants and its effect on mango quality were assessed. Finally, a sensory test was carried out on protected and non-protected mango to compare results of the stakeholders' view.

Study areas and material

The survey was performed in Parakou municipality, Department of Borgou, Central Region of Benin (Figure 1). The sensory test was performed using mango cultivar "Gouverneur" which presents a commercial importance in Benin. The mango samples used for sensory test come from a mango orchard at Korobourou (9°371 N / 002°6708 E), municipality of Parakou. The orchard of Korobourou is one of the orchards where biological control of mango pest by the use of weaver ants (*O. longinoda*) is done. This orchard is a homogeneous mango orchard with cashew trees nearby.

Survey

Face to face interviews were carried out with stakeholders (18 farmers, 21 women mango-pickers and 51 consumers) in April (mango middle ripening season in Benin) 2012. The survey aimed at identifying various criteria used by stakeholders to appreciate the quality of the mango and assessing their knowledge of weaver ants. Moreover, the survey focused on ants' effect on mango quality and the difference between mango from ant trees (protected mango) and mango from trees without ants (non-protected mango). Respondents were randomly selected from mango orchards (farmers and mango-pickers) and from the city (consumers).
The data collected from this survey were used to determine the parameters to be evaluated for the sensory test.

Sensory test on mango fruits

The sensory test was performed on mango samples, "gouverneurs" cultivar under laboratory conditions. Samples of about 40 fruits per category were harvested from two groups of trees (control and ants trees) in the experimental site of the orchard. For the control treatment, mango trees were not colonized by weaver ants; for the ant treatment, mango trees were colonized by weaver ants at a high level that may assure pest control, but ants' density data were not registered. The trunk of control trees was covered with a band of grease at 50 cm above the ground to prevent ants from climbing these trees. Also, the control trees were pruned so that their longer branches do not touch the branches of other trees around; grasses under and around them were regularly cleaned off. On a tree colonized by ants, we can see some fruits carrying scale insects (Figure 2). During our on-farm research activities we did not encounter scale insect on mango trees which are not colonised by weaver ants. For this reason, during the sensory test, for non-protected mango fruit called control mango, we consider only one type of fruit; but for protected mango fruit called ants mango, we consider two types of fruits: ants mango without scale insects and ants mango with scale insects.

So, for the sensory test, tree categories of mango fruits (control mango, ants mango without scale insects and ants mango with scale insects) have been analysed. Control mango fruits (CM) were picked from control trees, whereas ant mango without scale insects (AM) and ant mango with scale insects (AMS) were picked from ant trees. Mango fruits (40 fruits per category) were randomly selected from the four zones (north, south, east, and west) of trees. All the mango fruits harvested had similar degree of maturity, approximately similar size and were at physiological maturity stage. After harvest, mango fruits were transported to the laboratory. Fruits

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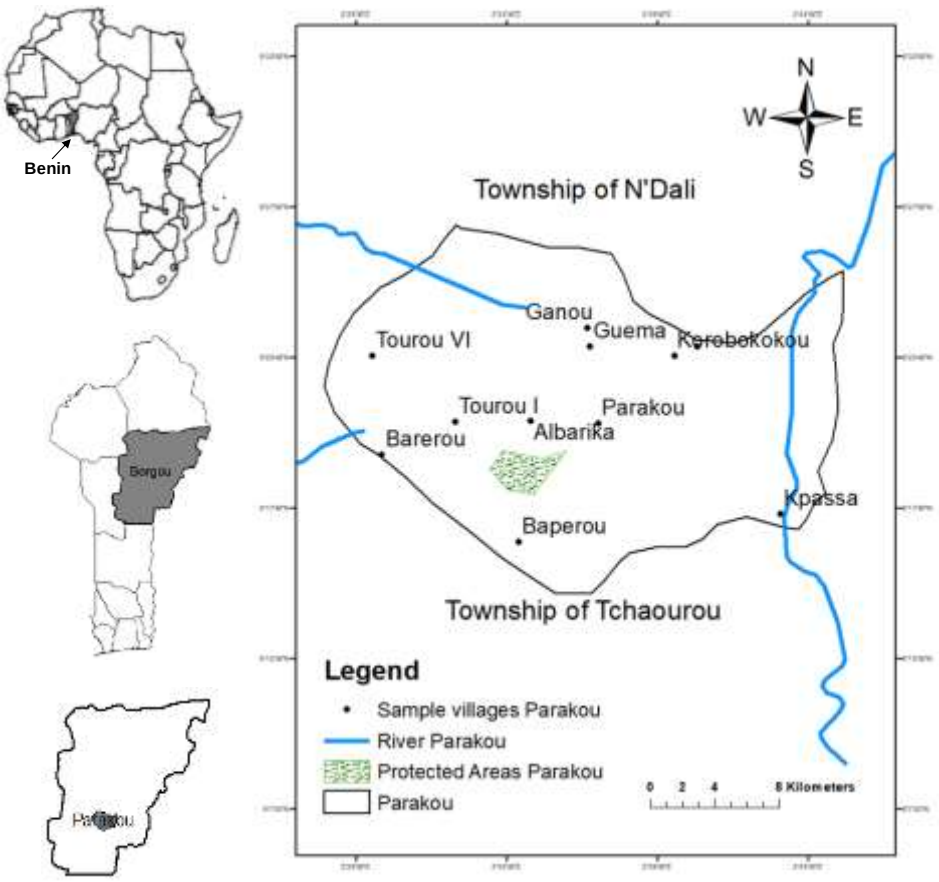

Figure 1. An overview of the study area.

Figure 2. Mango with scale insects and weaver ants patrolling on it for honeydew collect.

Table 1. Score performed by criteria used for assessing mango quality.

Stakeholders	Appearance	Maturity	No-infestation	Size	Firmness
Farmers (n=18)	16	16	16	16	15
Pickers (n=21)	5	17	11	14	11
Consumers (n=51)	22	43	21	15	31
Total (n=90)	43	76	48	45	57

Each value represents the number of stakeholders who mention the criteria.

were allowed to ripe fully (apparent maturity stage) at room temperature (25-28°C) before the test. The taste and appearance of the three categories of mango (Control Mango, Ants Mango, Ants Mango with Scale insects) were evaluated using 25 panellists. The choice of these two parameters (appearance and taste) was based on the survey resuts. Appearance was evaluated on unwashed and washed mango since pickers used to wash mango before exposing it for sale. Unwashed and coded mangoes are presented to the panellists for appreciation. After their appreciation, the same fruits were carefully washed, and re-presented to the panellists for new appreciation. For taste appreciation, a coded slice of each mango sample was presented to the panellists. Sensory quality assessment was realised using hedonic test with quantitative scaling approach value of 1 to 5. For each parameter analysed, each panellist provided a grade ranging from 1 to 5 to each sample; the highest note being attributed to the sample of best quality. At the end of the test, the average score obtained by each sample was calculated for each parameter evaluated.

Statistical analysis

Data collected from the survey were analysed using R system. Chi-square test was performed on contingency tables to see if the perceptions depend or not on the categories of respondents. When in contingency table, more than 20% of cells contain census data less than 5 or 1; the Fisher exact test was used instead of Chi-square test. Test of comparison of proportions was also performed to see if there is significant difference in the respondents' opinions. Sensory test data were analyzed with non-parametric Wilcoxon tests (because of lack of normality and variance homogeneity in the data).

RESULTS

Criteria used by stakeholders to assess mango quality

Different criteria were used by the stakeholders to appreciate mango: maturity, firmness, size, appearance, non-infestation by fruit flies and aroma (to a less extent). Table 1 presents score performed by each criterion according to different stakeholders. The quality criteria used varied according to stakeholders (Figure 3A). Consumers used the maturity as main mango quality criteria. But pickers, on the contrary, rely on the size to choose a mango. But the perceptions on each criteria did not vary among categories informants (P-value>0.05). Indeed, more the mango is fully ripe (Figure 3B), firm (Figure 3C) and big (Figure 3D), more it is of best quality whatsoever is the respondent. Considering all groups of respondents (consumers, pickers and famers), maturity is the first criterion of choice (84.4%). The firmness was the second criterion of choice (63.3%), followed by the non-infestation, size and appearance with 53.3; 50 and 47.8% of the interviewers, respectively.

As each criterion scored different number of stakeholders, proportion of stakeholders (about opinions on each criterion) is calculated based on the score of each criterion. As far as maturity is concerned, 82.9% of respondents (using this criterion as quality criterion) whether they are farmers, pickers or consumers preferred fully ripe mango fruits. When it comes to the firmness, preference was given to firm mango by 80.7% of concerned respondents, while 17.5% of them preferred soft mango. Regarding the size, almost all stakeholders using this criterion prefer a very big or a big mango fruit. Finally all respondents who mentioned the non-infestation prefer mangoes which are not contaminated by pest larva. To summarize, a mango fully ripe, firm, big and exempted of pests is globally preferred by stakeholders. In this paragraph, for each criterion, percentages relate to number of stakeholders using the criterion.

Stakeholders' perception of weaver ants and their effect on mango fruits

The knowledge of weaver ants did not depend on category of respondents (Fisher's Exact Test P-value = 0.8209). Farmers, pickers as well as consumers were aware of the existence of weaver ants. The proportion (94.4%) of respondents who knew about the occurrence of weaver ants is significantly higher than the proportion (5.6%) of respondents who did not know about the existence of weaver ants (P-value < 2.2e 16). In the further course of this paragraph, all percentages were calculated based on number of respondents knowing the existence of weaver ants (total of 85 respondents constituted of 18 farmers, 20 pickers and 47 consumers). When it comes to the perception of weaver ants effect, 75.3% of stakeholders (who knew about the occurrence of weaver ants) admit differences between mango fruits harvested from trees colonized by ants (protected mango) and those harvested from non-colonized trees (non-protected mango). Only 4.7% of them did not point

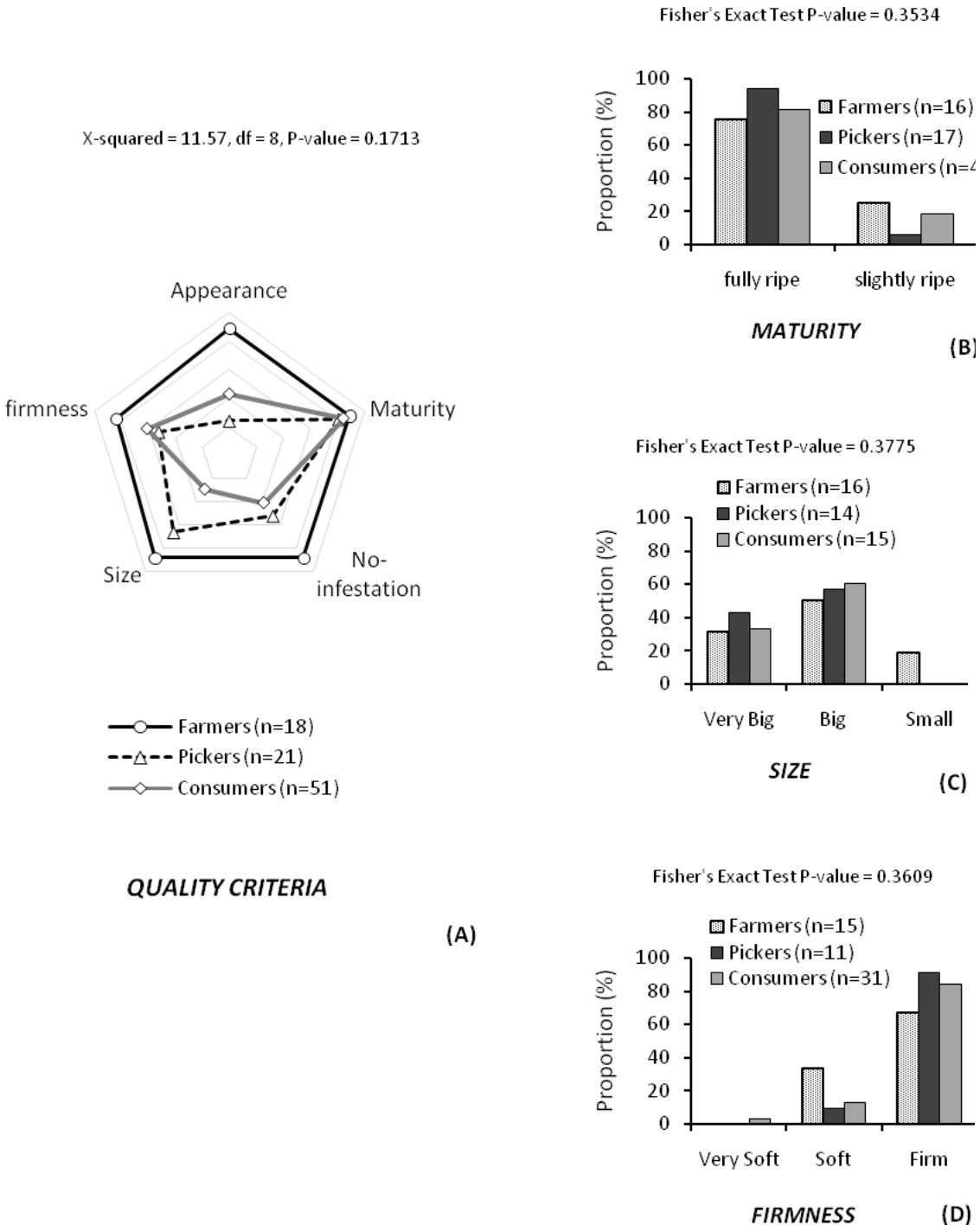

Figure 3. Main quality criteria used by stakeholdersfor mango choice. (A) Importance of criteria according to stakeholders; (B) Stakeholders opinion on mango maturity; (C) Stakeholders opinion on mango size; (D) Stakeholders opinion on mango firmness.

out any difference between the two categories of mango whereas the remaining 20% (constituted only of consumers) were without opinion. Statistic test (Chi-squared = 70.3, df = 2, P-value = 5.348e-16) showed significantly high difference between the proportion of respondents who admitted difference between PM and NPM and the proportion of respondents who did not. Perception of weaver ants' effect on mango fruits (Figure 4) varied according to category of stakeholders (Fisher's Exact Test P-value = 7.291e-05). Whereas all pickers

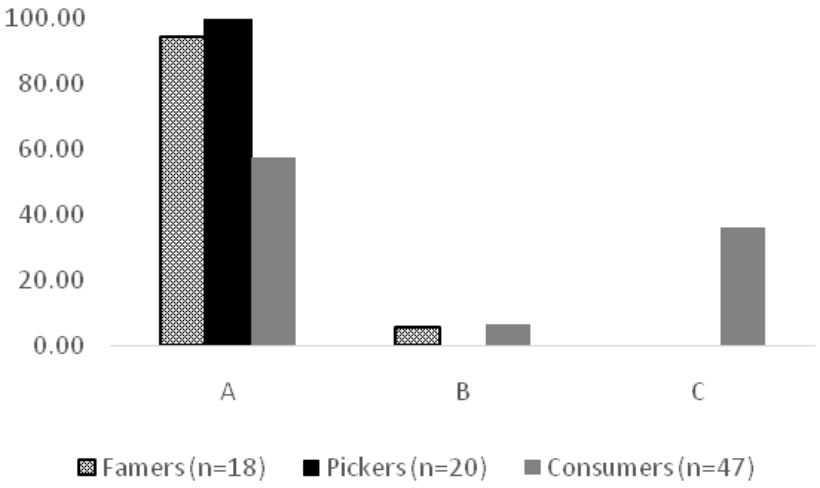

Figure 4. Perception of weaver ants' effect on mango fruits according to different Stakeholders. A: Proportion of different stakeholders admitting difference between protected and non-protected mango; B: Proportion of different stakeholders founding no difference between protected and non-protected mango; C: Proportion of Stakeholders without opinion.

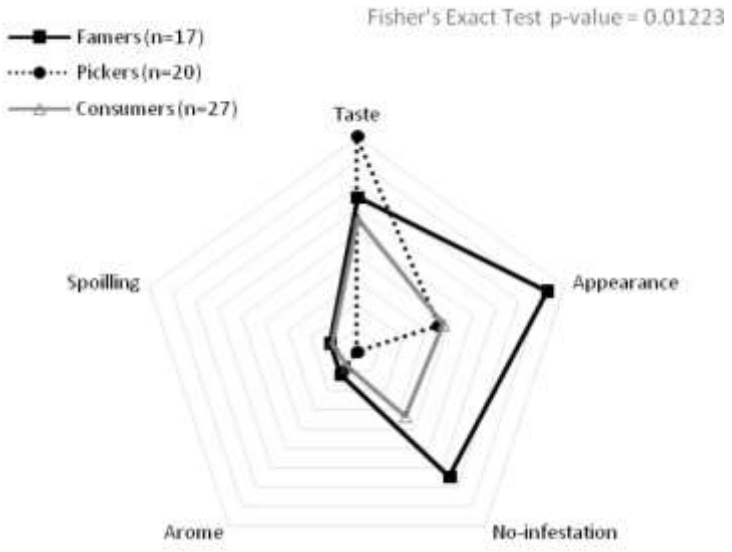

Figure 5. Criteria of difference between protected and non-protected mango.

and farmers admitted that there are differences between protected and non-protected mango, only 57.5% of consumers admitted differences between the two categories of fruits.

Criteria making difference between protected mango and non-protected mango

According to the interviewers, the differences between protected mango (PM) and non-protected mango (NPM) concern mainly the taste, appearance and non-infestation by fruit flies (Figure 5). For non-infestation, respondents mean absence of fruit flies larva inside mango pulp. So in the present study, the term non-infestation refers to absence of fruit flies attack. The criteria of difference perceived varied from one group of stakeholders to another (Fisher's Exact Test p-value = 0.01223). The appearance, taste and non-infestation were the main criteria making the difference between PM and NPM

Table 2. Repartition of stakeholders according to criteria of difference between PM and NPM.

Stakeholders (*)	Taste	Appearance	No-infestation	Aroma	Spoilling
Farmers (n=17)	11	14	11	2	2
Pickers (n=20)	18	7	0	2	0
Consumers (n=27)	15	10	9	2	3
Total (n=64)	44	31	20	6	5

(*) This table concerns only respondents who admitted that there is a difference between PM and NPM.

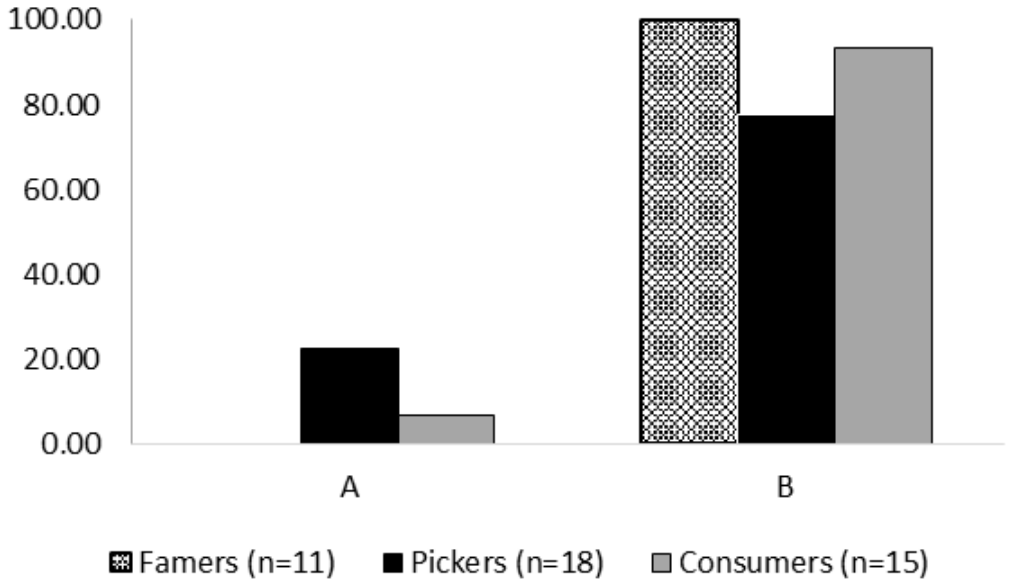

Figure 6a. PM and NPM comparison according to stakeholders using taste as difference criterion
A: Proportion of stakeholders saying protected mango (PM) is less sweet than non-protected mango (NPM). B: Proportion of stakeholders saying protected mango (PM) is sweeter than non-protected mango (NPM)

mentioned by farmers while the taste was the main difference of criterion for pickers. As for consumers, taste was the first criterion of difference followed by appearance and non-infestation. Few respondents mentioned aroma and spoiling as difference criterion.

Globally each respondent mentioned one or several difference criteria. Table 2 presents the numbers of stakeholders admitting difference between PM and NPM according to criteria of difference they mentioned. Considering all stakeholders, taste is the most important criterion of difference between PM and NPM followed by appearance, non-infestation, aroma and spoiling (Chi-squared = 52.396, df = 4, p-value = 1.14e-10). Taste is considered as criterion of difference by 68.8% of respondents who admit difference between PM and NPM; appearance by 48.4%, non-infestation by 31.3%; aroma by 9.4% and spoiling by 7.8% of the respondents. All these percentages relate to number of respondents admitting difference between PM and NPM (64 respondents among which 17 are farmers; 20, pickers and 27, consumers). As taste and appearance were the two most important criteria of difference between PM and NPM, they were used for the sensory test.

Comparison between protected mango and non-protected mango

For the comparison, only respondents who admitted difference between protected and non-protected mango were considered. These respondents mentioned one or several difference criteria. So percentage concerning a criterion is related to number of respondents using that criterion (Table 2). About 88.6% of stakeholders who considered taste as criterion of difference say that protected mango fruits are sweeter than non-protected ones (Figure 6a). Figure 6b shows the opinion of respondents who considered appearance as criterion of

Table 3. Sensory characteristic of mango according to panellists.

Treatment	Appearance		Taste
	Unwashed mango	Washed mango	
Control mango	3.9 ± 0.4[a]	2.7 ± 0.2[b]	2.8 ± 0.2[c]
Ants mango	3.2 ± 0.4[b]	3.2 ± 0.1[a]	3.9 ± 0.2[b]
Ants mango scale	2.6 ± 0.5[b]	3.8 ± 0.4[a]	4.5 ± 0.1[a]
Wilcoxon statistic	Chi-square = 37.5; df = 2; P < 0.0001	Chi-square = 35.9; df = 2; P < 0.0001	Chi-square = 83.5; df = 2; P < 0.0001

For each parameter (in the same column), means with same letter are not significantly different at 5%.

difference. According to 64.5% of these respondents, protected mango fruits have on their peel some marks which non protected mango fruits do not have. Moreover, some of these respondents (35.5%) negatively pointed out the presence of scale insects on the peel of protected mango. On the other hand, all respondents who considered fruit fly infestation as difference of criterion declared that protected mango fruits are not generally infested by fruits flies because they found no or less larvae inside these categories of mango fruits. As for the aroma, only six respondents mentioned it as criterion of difference; and four (04) of them found that protected mangoes have better aroma than non-protected ones whereas the other two said the opposite, claiming that weaver ants leave an unpleasant smell on protected mango fruits. Finally, all respondents (5/5) who evoked spoiling as difference of criterion declared that non-protected mangoes spoil faster than protected mangoes.

Sensory quality of protected and non-protected mango fruits

The organoleptic test realized on control mango (CM), ants mango (AM) and ants mango with scale insects (AMS) showed significant differences among treatments for the appearance (of washed and unwashed mango) and taste (Table 3). Concerning appearance, the panelists preferred control mango to ants mango when the fruits were unwashed. After washing, the opposite trend was observed, with AMS being the most preferred. Similarly, the panelists attributed the highest score to AMS for the taste. They asserted that AMS followed by AM are sweeter than CM.

DISCUSSION

Stakeholders' perception of mango quality and *O. longinoda* effect on mango fruits

This study shows that maturity, firmness, size and non-infestation by pests are the main criteria all stakeholders used to assess mango quality. It occurred that the perceptions of mango quality did not depend on the categories of stakeholders (Figure 3A). So whether they are farmers, pickers or consumers, all respondents perceived mango quality in same way. This similarity of perception may be due to the fact that generally, farmers and pickers are also mango consumers.

Even though the stakeholders perceived mango quality same way, they did not appreciate *O. longinonda* effect on mango quality accordingly. According to the farmers and pickers there is difference between protected mango (PM) and non-protected mango (NPM). As they are directly involved in harvesting and always in contact with orchard, they are used to check the two categories of mango before picking. Most of the people having no opinion about the question of difference between PM and NPM were consumers. This is probably due to the fact that they have no enough contact with mango orchards. Proportion of respondents who admitted difference between PM and NPM was significantly higher than the proportion of respondents who did not. The difference between PM and NPM was differently perceived by the respondents. Farmers' main difference criteria concerned appearance and non-infestation while pickers' were essentially taste and appearance (especially scale insects presence). Consumers use mostly these three criteria. According to the respondents, weaver ants leave some marks and / or small black spots on mango. Previous studies reported two types of marks which are produced by weaver ants on mango fruits: ant marks which are visible and caused by the deposition of formic acid when the ants catch prey (Peng and Christian, 2009), and anal spots which are produced by the ants as territorial pheromones and cues of interspecific competition (Hölldobler and Wilson, 1978; Offenberg et al., 2004; Offenberg, 2007). Farmers are more concerned with appearance and non-infestation certainly because these parameters may affect their income. For example, weaver ant marks (due to formic acid deposit) which affect PM appearance leads to their downgrade in certain countries such as Australia (Peng and Christian, 2009). Non-infestation might reduce post-harvest lost, enhancing then farmers' gain. Pickers are more concerned with taste and appearance difference probably because these criteria may impact their sales as consumers prefer

sweetest fruits. Globally, taste, appearance and no infestation are the most difference criteria between protected and non-protected mango used by all categories of respondents (consumers, pickers, famers).

According to respondents, PM is sweeter than NPM and PM are not infested by fruit flies. In Guinea, 57% of producers reported that mangoes protected by *O. longinoda* are sweeter than those unprotected (Van et al., 2009). But appearance of PM is unpleasant to pickers and consumers because of ants' marks and particularly the presence of scale insects. Although this unpleasant appearance, pickers prefer PM with scale insects saying there are the sweetest and are ready to wash them before exposing for sale. They even declare that once washed mangoes with scale insect have better appearance. This quality improvement of fruits protected by *O. longinoda* has been already reported. Sixty percent (60%) of Benin producers (involved in the experimental use of weaver ants for crops protection) believe that *O. longinoda* improves the quality of protected crops in terms of appearance, flavor, and texture (Sinzogan et al., 2008). Also better quality (taste, color) of citrus protected by *O. smaragdina* has been mentioned by the producers of the Mekong Delta in Vietnam (Barzman et al., 1996).

Weaver ant's protection and sensory quality improvement

Sensory test showed a significant difference between tastes of the three category of mango evaluated (Table 3). This result confirmed the better taste of protected mango mentioned by stakeholders during the survey. Likely the respondents' view on protected mango appearance, the sensory test for the appearance of unwashed mango attributed the lowest score to protected mango with scale insects. But once the mango fruits have been washed and the appearance test being repeated, the highest score went to PM with scale insects. So, the appearance test performed on washed mango showed that really weaver ants improve the appearance of mango fruit. But the improvement of the appearance was perceptible only after washing. This may explain pickers' behaviour who despite the unpleasant opinion of the consumers about PM appearance, prefer to harvest PM especially those with scale insects and wash them before exposing for sale. Similar to this result, a better shininess of citrus protected by *O. smaragdina* has also been reported in South Asia (Barzman et al., 1996). Indeed, many statements in relation with possible quality improvement of fruits protected by the ants have been reported by several scientists (Van Mele et al., 2009; Sinzogan et al., 2008; Barzman et al., 1996). Crops quality improvement associated with the use of weaver ants as biological control agent had been assessed through this sensory test for the first time. The concordance between the survey and the sensory test results opens pathway for further exploration to make out other unknown properties of weaver ants. Yet, besides their efficiency in biological control of crops pests, recent studies brought out some properties of weaver ants such as ability to ameliorate pollination by deterring less effective pollinators (Gonzálvez et al., 2013) or ability to slow global warming by boosting CO_2 absorption (Dorn, 2014).

Conclusion

This study highlights the ability of African weaver ants (*O. longinoda*) to improve mango quality. For the first time in Benin, the characteristics of mango fruit as desired by stakeholders have been established. The ideal mango fruit according to the respondents is a mango that is fully ripe, firm, big and exempted of pests attacks. The investigation revealed that African weaver ants (*O. longinoda*) improve mango quality especially taste, appearance and non-infestation. The sensory test confirmed the survey results. This advantage of weaver ants could be used to enhance their acceptability by farmers who are sceptical of adopting them.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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