HONEY BEES AND CASHEW FARM INTEGRATION IN COTE D'IVOIRE

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Abstract

Pollination is critical in cashew production and integration of honey bee colonies into orchards improves yields of raw cashew nut (RCN). Hive products provide additional income to farmers. RCN yields in Cote d'Ivoire remain one of the lowest in West Africa. The study investigates effects of increased pollination on nut yields and also the additional income from beekeeping. In 3 study sites in Seguela, Tortiya and Boundiali, 30 cashew farms with very similar characteristics were selected, marked and sizes measured. On each of 15 selected farms, 6 honey bee colonies were installed. Treated farms were paired with controls spaced 3 or more kilometers apart and without honey bee colonies. Three (3) out of the 6 colonies were put under weighing scales in June/July 2016 and weighed weekly. In March, 2017, honey, beeswax and propolis were harvested and yields recorded. RCN yields on all 30 farms were recorded at 2-week intervals. Seguela recorded a 97.9 % increase in RCN production on farms with bees. In Boundiali, a mean production increase of 40.7 % was recorded. However results in Tortiya were mixed; one farm with bees and its control recorded the highest percentage yield increase of 157.29 %. A mean 46.11 % production increase was recorded in Tortiya on orchards without bee compared to controls. Generally, 11.32 % production increase occurred on farms with bees. A mean of 15.7 kg honey, 0.30 kg beeswax and 0 32 g propolis were harvested per colony.

Key words: pollination, nut yields, honey, improved income

(Mots clés: Pollinisation, production en noix, miel, revenu amélioré)

1.0 INTRODUCTION

The world demand for cashew nuts outstrips supply. Pollination is critical in cashew production and many scientific studies have shown that low yields of cashew farms are as a result of under pollination of flowers. Cashew nut yields are known to increase significantly with insect visitation to flowers (Mcgregor, 1976). To optimize nut yields of cashew farms, it becomes necessary to

adopt measures to augment the populations of naturally occurring pollinators within the cashew agro-system (Freitas and Paxton, 1998). Integration of honey bee colonies into cashew orchards is one option which improves pollination and yields of raw cashew nut (RCN). The harvesting of valuable hive products from bee hives provides additional income to farmers. Raw cashew nut yields in Cote d'Ivoire remain one of the lowest in West Africa. The country recently became the largest producer of cashew nuts with a production of about 700,000 tons compared to almost zero tons 25 years ago (ACI Yield Survey 2010). This impressive growth, however, is as a result of increased land area put to cashew production. Initiated primarily as a strategy to fight against desertification, cashew production techniques and field structuring have received less attention compared to other crops such as coffee and cocoa. This has changed since the inception of the Council of Cotton and Cashew nut (CCA) in 2013, but the productivity per cashew tree and per hectare remains low. An ACi survey in 2010 and 2015 quantified the productivity of 3.36 kg of raw cashew nuts (RCN) per tree in 2010 and 5.24 kg per tree in 2015 (ACi yield survey 2010 and 2015). The yield per hectare of RCN is also low compared to other West African countries, averaging 522.4 kg per ha (ACi/CCA yield Survey 2015; Table 1)

Table 1: Baseline Production figures for 2010 in some African countries compared to India & Vietnam

Source: GiZ/ACi 2010. Analysis of the Cashew Sector Value Chain in Africa,. Eschborn. Germany

Country	**Yield/tree (kg)**	**Yield /ha in Kg (70 trees)**
Ghana	3-6.5	210-455
Benin	2.5	175
Burkina Faso	4-10	280-700
Cote d'Ivoire	1-2	70-140
Mozambique	1.5-2	105-140
Tanzania	2.5-5	175-350
Sene-Gambia	1.5-2.4	105-168
India & Vietnam	17.1	1200

These figures show a huge opportunity for Côte d'Ivoire to improve productivity and thereby strengthen its position on the world's scale. As part of its rehabilitation and development component of mining areas, the project "Property Rights and Artisanal Diamond Development II" (DPDDA II) in Côte d'Ivoire, funded by the US Agency for International Development (USAID) and the European Union launched a debate in 2014 on the possibility of promoting beekeeping in areas of cashew production, which is well practiced by the mining communities. While researching, the project found a 2013 study produced by the African Cashew Initiative (ACi), led by the German Cooperation (GIZ), which demonstrated that the introduction of beekeeping into cashew production increased RCN yields by 116.7 % in Ghana and 212.5% in Benin (Aidoo *et al*, 2013). It is therefore

theoretically possible that beekeeping could not only diversify the sources of income of communities dependent on cashew or mining, but can also double the productivity of cashew farms. The study investigates the effect of increased pollinator presence on nut yields in orchards in Cote d'Ivoire and also finds out possible additional income to farmers from the harvest of bee products.

2.0 Materials and methods

2.1The study sites

The study was carried out between September 2015 and August, 2017. Study sites were located in the agricultural landscape of northern Cote d'Ivoire where cashew nut production is a predominant farming activity. Study farms were selected in Seguela (N 760349.103; W893449.916), Tortiya (N 207438; W 968362), and Boundiali (N 6.4701230.00; W 9.450796).

2.2 Experimental treatments and set up

Thirty (30) cashew farms with very similar characteristics (size, age, and management) were selected, marked and actual sizes measured with GPS. Fifteen (15) out of the 30 selected farms were each installed with 6 honey bee colonies in Langstroth hives. Farms with installed bee colonies were paired with controls that were spaced 3 km or more apart and without managed honey bee colonies. Three (3) out of the 6 colonies were put under weighing scales in June/July 2016 and weekly weights were recorded. In March 2017, three bee products (honey, beeswax and propolis) were harvested from the experimental colonies which had good stores (hive weights of 60 kg or more) and yields recorded. RCN yields on all 30 farms were recorded at 2-week intervals from January to June, 2017. At each RCN harvest, samples of 500 nuts were randomly taken on each farm, weighed and the weight recorded.

3.0 RESULTS

3.1Raw cashew nut (RCN) production of farms with and without bee colonies

3.1.1 Production in Seguila

Raw cashew nut production figures on farms in Seguela are shown in Table 2. Nut yields on farms with bee colonies and those without are compared in Figure 1

Table 2: Yields of RCN on farms with and with no bee colonies in Seguela during the 2016/2017 season

Farm number	Yields of A farms with bees (kg/ha)	Yields of B farms with no bees (kg/ha)	Mean percentage increase yield of farms
S1	147.13	592.6	-302.8
S2	290	328.1	-13.1
S3	676	148.7	354.6
S4	380	90	322.2
S5	444	194.3	128.5
TOTAL	**1937.13**	**1353.7**	**489.4**
MEAN	**387.43**	**270.74**	**97.9**
RANGE	**147.13 - 676**	**90 – 592.6**	**-302.8 – 354.6**

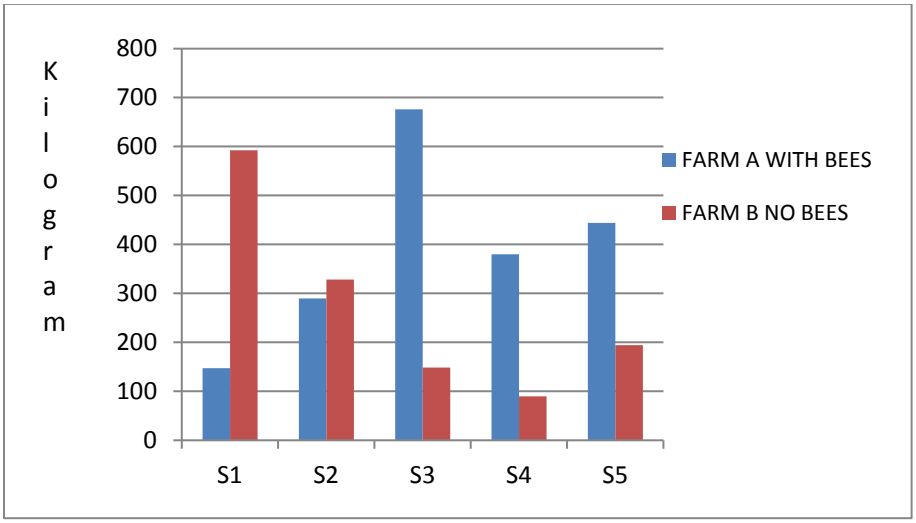

Figure 1: Comparing RCN yields (kg/ha) on farms with and with no bee colonies in Seguela during the 2016/2017 season

3.1.2 Production in Bundiali

Raw cashew nut production figures on farms in Bundiali are shown in Table 3. Yield values on farms with bee colonies and those without are compared in Figure 2.

Table 3: Yields of RCN on farms with and with no bee colonies in Bundiali during the 2016/2017 season

Farm number	Yields of A farms with bees (kg/ha)	Yields of B farms with no bees (kg/ha)	Mean percentage

			increase yield of farms
B7	245	157	56.1
B8	330	267	23.6
B9	397	249	59.4
B10	462	374	23.5
TOTAL	1434	1047	**162.6**
MEAN	**358.5**	**261.75**	**40.7**
RANGE	**245 - 462**	**157 – 374**	**23.5 – 59.4**

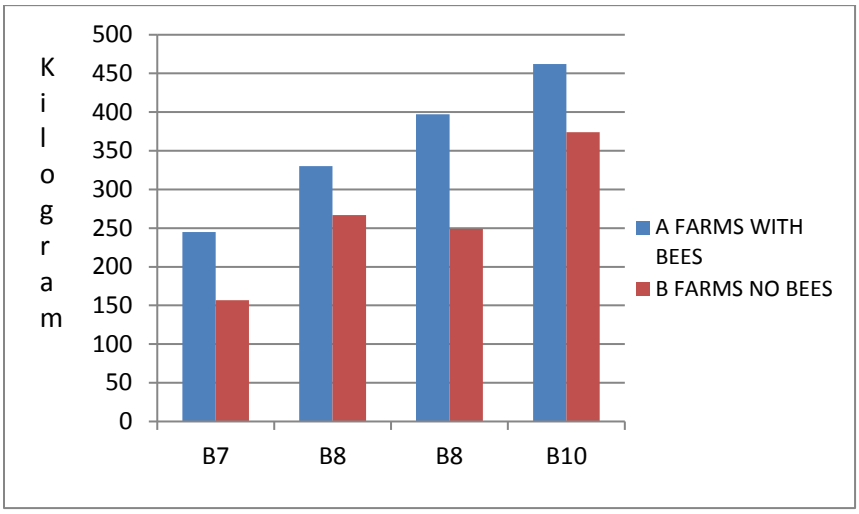

Figure 2: Comparing RCN yields (kg/ha) on farms with and with no bee colonies in Bundiali during the 2016/2017 season

3.1.3 Production in Tortiya

Raw cashew nut production figures on farms in Tortiya are shown in Table 4 Yields on farms with bee colonies and those without are compared in Figure 3.

Table 4: Yields of RCN on farms with and with no bee colonies in Tortiya during the 2016/2017 season

Farm number	Yields of A farms with bees (kg/ha)	Yields of B farms with no bees (kg/ha)	Mean percentage increase yield of farms
T11	382.9	520.66	-36
T12	193.88	508.03	-162.03
T13	319.33	890.12	-178.75
T14	546.35	212.35	157.29
T15	363.57	403.82	-11.07
TOTAL	**1806.03**	**2534.98**	**-230.56**
MEAN	**361.21**	**507**	**-46.11**
RANGE	**193.88 – 546.35**	**212.35 – 890.12**	**-36 – 157.29**

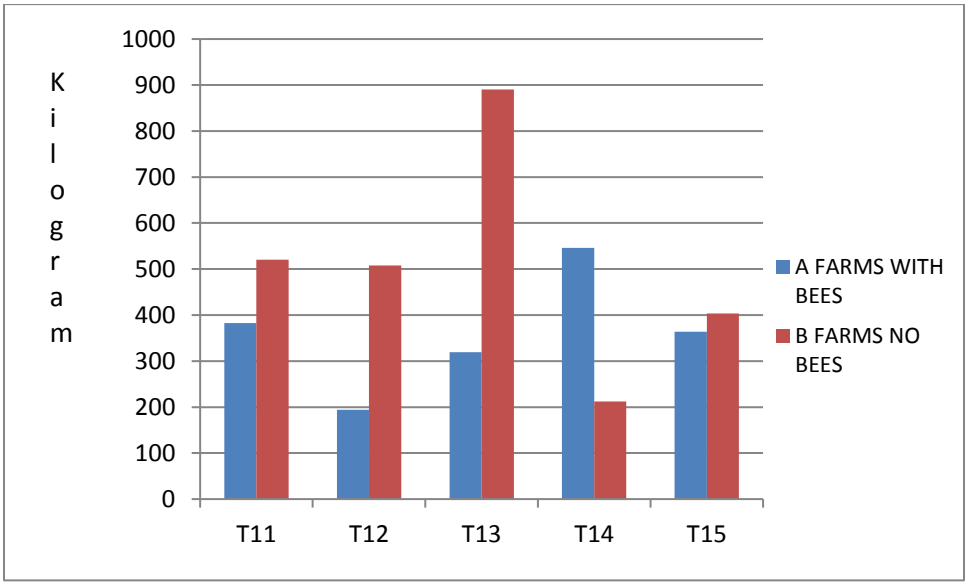

Figure 3: Comparing RCN yields (kg/ha) on farms with and with no bee colonies in Tortiya during the 2016/2017 season

3.1.4 Summary of RCN yields on all experimental farms

Mean values of RCN yield of 369.05 kg/ha was obtained on farms with bees as compared to 346.5 kg/ha on those without bees. This shows an increase yield of 11.32 % on the farms with integrated honey bee colonies (Table 5).

Table 5: A summary of mean yields of RCN in all the study farms with or with no bees

Study site	Mean yields of A farms with bees (kg/ha)	Mean yields of B farms with no bees (kg/ha)	Mean percentage increase yield of farms (%)
SEGUELA	387.43	270.74	43.1
TORTIYA	361.21	507	-46.11
BOUNDIALI	358.5	261.75	36.96
TOTAL	**1107.14**	**1012.79**	**33.95**
MEAN	**369.05**	**346.5**	**11.32**

3.1.5 RCN yield per tree of the 3 study sites

A summary of RCN yield per tree on the experimental farms are shown in Table 6

Table 6: RCN yield per tree on all the farms with and with no bee colonies in the 2016/2017 season

Study sites	Mean yields of A farms with bees (kg/tree)	Mean yields of B farms with no bees (kg/tree)
BOUNDIALI	5.1	3.7
SEGUELA	5.52	3.9
TORTIYA	5.16	7.24
TOTAL	**15.78**	**14.84**
MEAN	**5.26**	**5.0**
RANGE	**5.1 – 5.52**	**3.7 – 7.24**

3.1.6 Quality of nuts on farms with and with bee colonies

Mean values of 500 nuts on farms with bees were 3.1 kg and 3.2 kg respectively on farms with and without bee colonies.

3.2 Colony development and bee hive products

3.2.1 Colony development

Seasonal development of honey bee colonies in the cashew belt as represented in Seguela during the 2016/2017 beekeeping season is shown in Figures 4 and 5.

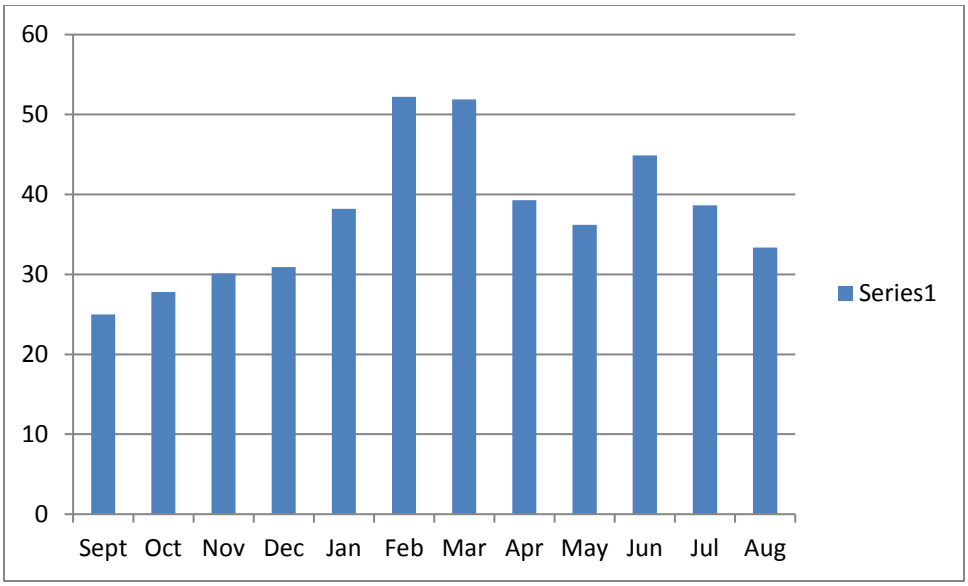

Figure 4: Monthly colony development during the beekeeping season of 2016/2017 in Seguela

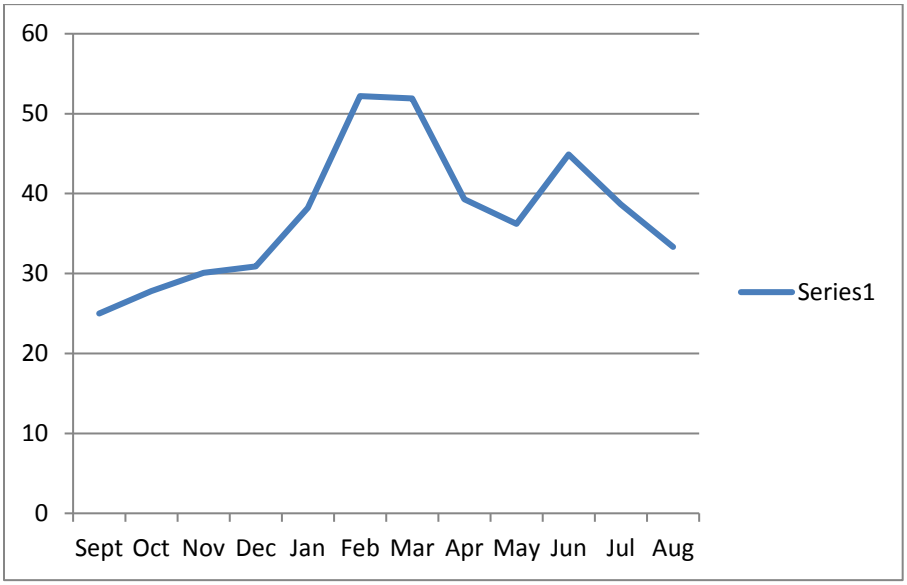

Figure 5: A graph showing the monthly colony development during the beekeeping season of 2016/2017 in Seguela

3.2.2 Honey production

Honey production in Seguela recorded the highest with a mean of 19.8 kg/colony, followed by Tortiya with 14.18 kg/colony and then Bundiali with 13.14 kg/colony. A mean of 15.7 kg of liquid honey was obtained per colony on the cashew farms studied. This quantity of honey has an estimated market value of 31,400.00 CFA. A second harvest of colonies in Seguila recorded a mean of 4.3 kg of honey with an estimated market value of 8,490.45 CFA.

3.2.2.1 Moisture content of honey

A mean moisture content of 18.1 % was obtained for honey harvested at the 3 study sites.

3.2.3 Beeswax production

Seguela recorded 0.38 kg per colony of refined beeswax, Tortiya 0.28 kg and Bundiali 0.25 kg. A mean value of 0.30 kg per colony of refined beeswax was obtained for the experimental sites. This has an estimated market value of 1,500.00 CFA.

3.2.4 Propolis production

A mean value of 32 g of propolis per colony was harvested from hives with an estimated market value of 6,000 CFA.

4.0 Discussion

Generally, raw cashew nut (RCN) production increased significantly on experimental farms where honey bee colonies improved the effectiveness of pollination. In Seguela 3 out of 5 farms with bee colonies had yield increases over controls. However on the remaining two farms, yields decreased on farms with bees as compared with farms without bees. There was a general production increase of 97.9 % (range -302.8–354.6 %) on farms with bees compared to those without (Table 2; Fig. 1). In Boundiali the trend was different from that of Seguela. All the experimental farms with bee colonies recorded higher yields of RCN as compared to farms without bees. There was a mean production increase of 40.7 % on farms with bees (Table 3, Fig. 2). Production in Tortiya did not respond to increased pollinator presence on farms provided by the installation of honey bee colonies. Only one farm had an increase of 157.29 % over its control. Four (4) control farms without bee colonies recorded higher RCN yield over their counterpart farms with installed colonies. There was therefore a mean production increase of 46.11 % on farms with no bees compared to those with bees in Tortiya. The mixed effect of increased presence of honey bee pollinators in cashew orchards in the study sites may be attributed to the fact that many other insect

have been found to visit and pollinate cashew flowers. In major cashew growing regions of the world, flower visitors including bees, butterflies, flies, ants and wasps have been recorded (Bhattacharya, 2004). A 2008 study in Ghana identified honey bee (*Apis mellifera*) in addition to two native stingless bees (*Dactylurina staudingeri* Gribodo and *Liotrigona parvula* Drachen) and seven solitary bees (*Compsomelissa sp., Brausapis sp., Halictus sp., Lipotriches sp., Lasioglossum sp., Ceratina sp. and Thyreaus sp.)* that form the important bee pollinator complex of cashew (Aidoo, 2008). The study found that honey bees act to compliment the pollination services that occur in cashew orchards. The cashew landscape in Seguela and Tortiya is rich in natural vegetation and forest. These provide good habitat and resources for many natural pollinators of the cashew crop including wild nests of honey bees. A critical study of the land cover in the two experimental sites using GIS satellite images showed that in Tortiya, there was 2650 ha of forest within a 3 km radius of farms used as controls. The average distance from control farms to the nearest forest areas was 76 meters. In Séguéla, the contrast is that there were only 285 ha of forest within a 3 km radius, and average distance to nearest forest areas was 260 meters. In other words, there is 9 times more forest within 3 km of fields in Tortiya than in Séguéla. This confirms the results where higher yields of RCN were obtained on control farms in Tortiya than in Seguila (507 kg/ha against 270.74 kg/ha). The assertion that abundance of naturally occurring pollinators in adjourning forests provided full complement of the pollinating services needed by cashew farms for optimum yields needs further scientific investigations. The highest RCN yields were generally observed on farms with additional honey bee colonies. An overall mean of 369.05 kg/ha was recorded as against 346.5 kg/ha (11.32 % increase) on farms without bees. These figures translate to 5.26 kg/tree and 5.0 kg/tree (using the ACi recommended 70 trees/ha) on farms with and without bees respectively. The production figures above show increases on figures quoted for Cote d'Ivore in the ACi study of 2010. Production values recorded during the study also compare favorably with those of Ghana (3–6.5 kg/tree; 210-455 kg/ha). In a similar study conducted in Ghana and Benin in 2013, RCN yields of 4.2-9.1 kg/tree and 294-637 kg/ha were recorded respectively for farms without bees and those with bees in Ghana. In Benin, there were 2.16 -6.75 kg/tree and 151.2 -472.5 kg/ha respectively (Aidoo *et al*, 2013). The yield values for Cote d'Ivoire obtained during the study season in 2017 fall within these ranges. Production figure in Cote d'Ivoire could improve if measures are put in place to effectively manage orchards using CCA/ComCashew recommended practices. Random planting of trees in orchards for desertification control has resulted in situations where tree populations have exceeded the recommended 70 trees /ha density. Rigorous culling of unproductive trees and pruning of overgrown tree must be carried out on farms. These will provide good orchard environment for higher productivity. The development of new farms should follow improved planting and cultural practices including correct plant spacing recommended by Council of Cotton and Cashew nut (CCA) in association with ComCashew. Observations made during the study showed that many trees in orchards produced numerous flowers that do not develop into fruits ("bouquet trees"). This is a phenomenon which may occur in orchards where trees have low sex ratios, producing more males than hermaphrodite flowers. Another reason for low nut yields could be the effect of self-incompatibility of trees in these orchards (De Holanda-Neto *et al*, 2002). Probably seeds used by farmers in developing these farms were taken from a single parent resulting in orchards with homogenous genetic composition. Such orchards have very low productivity. This assertion needs further scientific investigations where plant materials from cashew farms throughout the country are sampled and subjected to DNA analysis.

There were no significant differences between qualities of nuts produced on farms with bees compared to farms without bees. The weight of 500 nuts that were sampled on all the experimental farms was not significantly different. This is attributed to the fact that the cashew hermaphrodite flower has a single ovule and requires a single male gamete for fertilization (Elsy *et al*, 1986; Madhava Rao *et al*, 1957).

Climatic conditions in West Africa are similar and follow the seasonal dry and rainy seasons. Honey bee colony activities follow similar trends where food gathering and nest build up occur in the dry season. In the cashew belt studied and represented in Seguela, bee colonies followed the normal development regime during the 2016/2017 season where nest weights started increasing and reached a peak in February-March (Figs. 4 & 5). Hive products (honey, beeswax and propolis) were harvested during this time. A mean value of 15.7 kg of good quality liquid honey (moisture content 18.1 %) per colony for the study sites is similar to yields obtained in Ghana and Benin in 2013 (Ghana 20.7 kg; Benin 13.7 kg). A second honey harvest of 4.3 kg/colony recorded in Seguila is an indication of good forage resources that become available in the area in May/June. Beekeepers in such areas could take advantage of this resource and manage colonies for optimum production. Beeswax production average of 0.30 kg/colony is however low compared to figures in Ghana and Benin (Ghana 1.4 kg; Benin 0.92 kg). The only indication is that colonies made use of less wax in building honey combs. Propolis production of 32 g/colony was similar to figures obtained in Ghana and Benin (Ghana 37 g and Benin 26 g). Higher yields of hive products could have been obtained in all study sites if colonies were given additional space in their hives. In all the hives harvested, colonies had filled all spaces and worker bees were found clustering outside the bee hive. Beekeepers lacked technical knowledge on the management of Langstroth hives that were supplied. As a result of this the farmers contributed little to the management of colonies installed on their farms. Very important accompanying inputs for frame hive beekeeping such as comb foundations were absent. It is recommended that appropriate and low technology beekeeping systems such as provided by the use of top bar hives be introduced to farmers for easy adoption and for higher production.

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Figures