A Portable Device to Assist in the Harvest of Coffee in Colombia

Un Equipo Portátil para Asistir la Cosecha de Café en Colombia

Edilson León Moreno Cárdenas[1]; Carlos Eugenio Oliveros Tascón[2] and Fernando Álvarez Mejía[3]

Abstract*. The harvest is one of the most important activities in coffee crops; on the one hand, it provides employment opportunities for a large group of rural workers and on the other, it supplies mature fruits for the production of high quality coffee. In the present study, a device was designed and evaluated to assist in manual coffee harvesting, called Alfa, which employs a three-toothed blade beater, a DC motor powered by dry batteries and a system for receiving detached fruits. The research proceeded in two phases; in the first, the device was designed and built; in the second, an evaluation was carried out by using traditional manual collection as a comparison. The evaluations were developed in four locations: three experimental stations of Cenicafé and one private property. The variables studied were: number of fruits left on the ground after harvest, percentage of immature coffee in the harvested mass and yield. The device presented an operating time of four days without recharging, a weight less than four kg and an absence of technical failures; the operators had no problems with its use; and, in addition, it was possible to increase the yield of the operators by almost 70%; the percentage of immature coffee was between 4.5% and 3% and losses were between one and 19 fruits per site.*

Keywords: Yield, quality, losses, ergonomic device.

Resumen*. La cosecha es una de las actividades más importantes en el cultivo de café; de un lado proporciona empleo a un amplio grupo de trabajadores rurales y de otro brinda frutos maduros que contribuyen a la obtención de café de alta calidad. En la investigación un equipo llamado Alfa fue diseñado y evaluado para asistir la cosecha manual del café. El equipo consistió de un impactador de tres paletas dentadas, un motor DC accionado por baterías secas y un sistema para recibir los frutos desprendidos. La investigación contó con dos fases; en la primera el equipo fue diseñado y construido, en la segunda una evaluación fue adelantada empleando como comparación la recolección manual tradicional. Las evaluaciones se realizaron en cuatro localidades, tres centros experimentales de Cenicafé y una finca particular. Las variables en estudio fueron: número de frutos dejados en el suelo luego de la cosecha, porcentaje de frutos verdes en el café cosechado y rendimiento. El equipo presentó un tiempo de operación de 4 días sin recarga, el peso fue inferior a 4 kg y no se presentaron fallas técnicas. Los operarios no manifestaron problemas con su uso y fue posible incrementar el rendimiento de los operarios hasta en 70%, el porcentaje de café verde estuvo entre 4,5 y 3% y pérdidas entre 1 y 19 frutos por sitio.*

Palabras clave: Rendimiento, calidad, pérdidas, dispositivo ergonómico.

The harvest and postharvest of coffee represent up to 50% of total production costs (FEDERACAFÉ, 2012). The Federación Nacional de Cafeteros de Colombia has been promoting a strategy to implement a research program for coffee harvests through the National Coffee Research Center, Cenicafé, whose purpose is to contribute to the improvement of this activity as a whole and, therefore, to the sustainability of the coffee industry. A time and motion study in manual harvesting was the first research developed by Cenicafé; this study detected some movements that are part of the harvest cycle but which do not contribute to the yield and, therefore, should be eliminated; this study motivated the development of a new harvesting method which was called "improved hand-picking method" (Vélez *et al*., 1999; Vélez *et al.*, 2002; Martínez *et al.*, 2005). Similarly, others studies have been carried out with the purpose of adapting and evaluating the commercial equipment used in other countries to harvesting coffee and other products such as olives; for example, (Oliveros, 1999; García, 2001 and García *et al.*, 2001) modified and evaluated a device to harvest coffee cherries by beating the branches, reporting yields of up to 36.1 kg h^{-1}, detached mature fruits between 83% and 92.3% and green fruits in the harvested coffee between 38.3% and 4.3%. Díaz *et al.* (2009) evaluated the semi-mechanized coffee harvesting device: STIHL SP-81 at two locations in Colombia with the varieties Caturra and Colombia, helping to reduce the unit harvest cost by 41.4%, increasing the yield of operators by 102.5%, and with 11.5% to 15.8% of green fruits in the harvested mass (GHM), meaning that many green fruits must be removed to produce high quality coffee.

Other authors have also developed tools to assist in manual collection and increase the yield of collectors.

[1] Assistant Professor. Universidad Nacional de Colombia - Sede Medellín - Facultad de Ciencias Agrarias - Departamento de Ingeniería Agrícola y Alimentos. A.A. 1779, Medellín, Colombia. <elmorenoc@unal.edu.co>
[2] Lead Researcher. Centro Nacional de Investigaciones de Café, Cenicafé. Disciplina de Ingeniería Agrícola. km 4 antigua vía a Manizales. Chinchiná, Colombia. <carlos.oliveros@cafedecolmbia.com>
[3] Full Professor. Universidad Nacional de Colombia - Sede Medellín – Facultad de Ciencias Agrarias - Departamento de Ingeniería Agrícola y Alimentos. A.A. 1779, Medellín, Colombia. <falvarezme@unal.edu.co>

Received: November 27, 2013; Accepted: July 04, 2014. doi: http://dx.doi.org/10.15446/rfnam.v68n1.47833

For instance, Ramírez *et al*. (2006) developed and tested a device called DESCAFÉ III (coffee fruit sheller); with this equipment, the coffee is detached by the impact caused by three rotating rubber teeth evenly distributed on a truncated circular structure, driven by a 75 W DC motor which is powered by four batteries located in a harness transported on the back of the operator. In advanced evaluations with the device in Timbio (Cauca, Colombia) in trees with a ripe fruit concentration of 80%, operator yields of 39.4 kg h^{-1} with 3.5% to 6% GHM were achieved.

Oliveros *et al*. (2005) developed a portable device to assist in the manual harvest of coffee called IMFRA (Impactador de Frutos y Ramas - Impactor of Fruits and Branches), which consists of an actuator that weighs 850 g, is carried in the hand of the operator and houses a 84.7 W DC motor. The motor is powered by batteries located in a harness with a weight of 8 kg. The coffee cherries are detached when struck by two elliptical Teflon beaters, rotating at 1,100 rpm. The device was evaluated in the principal harvest of 2004 in Timbio (Cauca), with the red Colombia variety coffee, second harvest, planted at 1.5 x 1.0 m. The mature coffee load at the time of harvest was 1.43 kg $tree^{-1}$. The obtained yield was 33.7 kg h^{-1}, with 4.3% to 10.3% GHM; the detachment efficiency for mature fruit was close to 80%, requiring a second manual pass to remove the remaining 20%. Finally, the authors concluded that the device is a promising alternative to assist with manual coffee harvests in Colombia, especially in crops with a high density, that is a minimum load and concentration of ripe fruit of 0.7 kg $tree^{-1}$ and 50%, respectively.

This paper contains the most important components of a study that aimed to develop and evaluate a portable device to assist in the manual collection of coffee, called Alfa, which can be used in different coffee regions for increased yields when harvesting all of the available mature fruits and achieving levels close to the recommended maximums for immature coffee in the harvested coffee and the number of fruits left on the ground after harvest.

MATERIALS AND METHODS

Location. Field tests were conducted at the following sites:

a) Naranjal station of the National Coffee Research Center – Cenicafé, located in the municipality of Chinchiná (Caldas, Colombia) at 4° 59' North and 75° 39' West, at an altitude of 1,400 masl, with annual temperature and humidity averages of 20.8 °C and 78%, respectively, and an annual rainfall of 2,656 mm.

b) Catalina station of the National Coffee Research Center – Cenicafé, located in the municipality of Pereira (Risaralda, Colombia) at 4° 45' North and 75° 44' West, at an altitude of 1,321 masl, with annual temperature and humidity averages of 21.9 °C and 82%, respectively, and an annual rainfall of 2,202 mm.

c) The Guayabo Negro farm in Piendamó (Cauca, Colombia), located at 2° 38' North and 76° 30' West, at an altitude of 1,685 masl, with annual temperature and humidity averages of 18 ºC and 85%, respectively, and an annual rainfall of 2,099 mm.

d) Pueblo Bello substation of the National Coffee Research Center – Cenicafé, located in the municipality of Pueblo Bello (Cesar, Colombia), located at 10° 25' North and 73° 34' West, at an altitude of 1,134 masl, with annual temperature and relative humidity averages of 20.9 °C and 80%, respectively, and an average annual rainfall of 2,029 mm.

Equipment description. The equipment designed and used in the evaluations, called Alfa, is portable and designed to detach fruits in the glomeruli, individually or severally. The Alfa tool is integrated by an actuator and a harness. The actuator employs a beater with toothed-blades (Moreno *et al*., 2013) and a direct current electric engine of 15W and 160 g to detach mature fruits. Two dry batteries of 12 V and 2.2 A, placed in the harness supported at the waist of the operator, are used to drive the equipment (Figure 1). The harness weight is 3.6 kg and the detached fruits are collected with a tray.

Experiment. Before starting the harvest, the workers were instructed on the use of the Alfa device and tray. Afterwards, the collectors began harvesting with the Alfa equipment under constant supervision for one hour; this was a training activity in order to support the correct use of the equipment; then, they continued independently. For collecting with the Alfa equipment, each collector was placed on one side of the trees, moving along the rows in a coordinated manner. The crop conditions in each site were:

Naranjal station. The harvest was carried out on a lot with 2,300 trees planted with full-sun exposure, Colombia variety, first harvest, renewal pruning, with two stalks per site, planted at 2 m between rows and 1 m between trees, with an average slope of 10%. Two collectors were equipped for the harvest with an Alfa device and a tray to receive detached fruits, as proposed by Oliveros (2003).

Guayabo Negro farm. Tests were conducted in a lot planted with coffee variety Colombia at 1.6 x 1.6 m, first harvest, one stalk per site, average slope of 20%.

Figure 1. Equipment Alfa. a. actuator, b. harness and c. battery.

The tests involved two operators and each was given an Alfa device and equipment for receiving detached fruit, consisting of a basket and an extension of poly-shade mesh, placed at the base of the trees (Figure 2) and called Mallacán MC (Oliveros *et al.,* 2008).

Pueblo Bello substation. The evaluation was conducted in lots with Colombia variety coffee trees, second and third harvest, planted at 1.5 x 1.5 m, steep topography, with the presence of rocks and slopes of up to 80%. The harvest included two operators; each was given an Alfa device and basket with canvas to receive the fruit detached by the device (Oliveros *et al.,* 2008) consisting of a conventional basket and a canvas attached to its top that was extended and secured to the stalk of the harvested tree (Figure 2). Before starting the tests, the two operators formed a harvesting pair and received an orientation of 15 min for the Alfa device and traditional baskets with canvas. They then harvested for one day in order to become familiar with the technology. The two collectors were simultaneously positioned, one on each side of the harvested tree. For the first harvest day with the Alfa device, an incentive of $US 0.52 cents per kilogram of collected coffee was paid to promote its use.

Catalina station. The tests were conducted during the principal harvest of 2010 in three fields planted with the varieties Colombia and Castillo®, second, third and

Figure 2. System for receiving the coffee fruits, traditional basket with canvas.

fourth harvest, with between 2,827 and 4,746 plants, planted at 2 x 1 m and 3 x 1 m, with slopes between 10% and 50%. The evaluation involved six collectors; each was given an Alfa device and a "Tico" type basket, a container used for harvesting coffee in Costa Rica, whose dimensions are slightly larger than the traditional baskets used in Colombia. To improve the collection of the fruits detached by the device, a canvas was attached to each basket (Figure 3), similar to that used in the 2008 assessment at the Pueblo Bello substation (Oliveros *et al.,* 2008). At the beginning of the evaluation, three harvesting pairs were formed from the six operators, and then instructions on how to use the Alfa device and basket with canvas were given. For the harvest, each pair moved along a row with each operator harvesting one side of the trees (half of the tree). Harvesting with the Alfa device and the conventional method was carried out for six days using both systems every day, a half-day each.

In general, during the four evaluations, it was recommended that the Alfa device be focused on branches with medium and high ripe fruit concentrations (> 40% mature fruits) and that, for those branches with low concentrations, the operators should harvest manually, preferably using the "improved hand-picking method" (Vélez *et al.,* 1999), ensuring that the fruits were completely harvested without the need for a second pass. In all of the evaluations, to determine the average load of ripe coffee available (kg of ripe coffee per tree), 17 trees were randomly taken from each batch and harvested of all their coffee for subsequent weighing. Similarly, in each evaluation, the traditional manual collection with a basket was used as the comparison, that is, each collector carried out the labor in its usual form. The coffee harvested with the Alfa device and the manual method was weighed separately. The payment was by kg for both harvesting methods. The variables studied were:

Figure 3. System to receive the coffee fruits, "Tico" basket with canvas (Oliveros *et al.*, 2008).

Losses (Number fruits / tree). Indicates the number of fruits at any stage of development that were found on the ground after harvest; for the estimation, 20 trees were selected and the coffee at any development stage that was found on the ground was removed before the harvest and, once harvesting was done, the number of fruits present on the ground was counted.

Immature coffee in the harvested mass (GHM) (%). Each day, a sample of 1 kg of harvested coffee was taken, from which, the immature coffee was separated and weighed, and the percentage of immature coffee was obtained as the ratio between the two values, multiplied by 100.

Yield (kg h^{-1}). At the end of each day, the weight of the harvested coffee and hours worked were recorded, the yield was estimated as the ratio between the two values.

RESULTS AND DISCUSSION

Naranjal station. The availability of coffee in the lot was in line with the harvest season, with large differences between the minimum and maximum values, a common occurrence in the region. The average 748 g tree^{-1}, reflects the typical mature coffee supply for this coffee region.

Losses. Figure 4 presents the losses due to fruit left on the ground with the two harvest methods. With hand-picking, the results were consistent with those reported in previous evaluations, surpassing the recommended values for proper management of the coffee bean borer. Notably, most of the fruits found on the ground after manual collection were not mature but green, probably discarded during harvesting. With the Alfa device, in the first day alone, losses exceeded the recommended values, due to the operators' unfamiliarity with the trays. In the following days, the collectors became accustomed to the equipment and, after the second day, losses fell below the maximum values recommended for control of the coffee bean borer (Bustillo, 2002) and even values similar to those reported for coffee harvesting with mesh on the ground were attained (Oliveros *et al*., 2006).

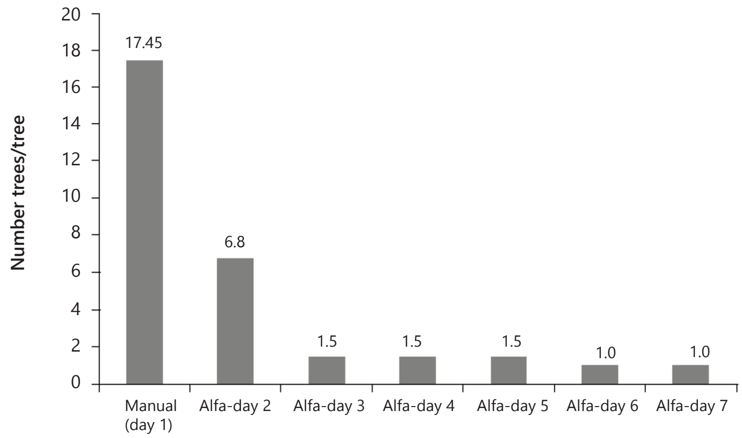

Figure 4. Coffee fruits left on the ground with Alfa device and manual gathering systems.

Harvested immature coffee. The results in percentage of harvested green fruits showed that the traditional manual collection complied with the recommendations for maintaining coffee quality (value less than 2.5%; Puerta, 2000). The first day of collection with the Alfa device had the highest amount of detached immature coffee, exceeding the recommended maximums; this was due to three factors: the amount of mature coffee available on the trees, the payment (after the first day, the activity was paid by kg, so they needed to work very fast in order to not lower their harvest yield when the new equipment was used) and the available amount of time for the acquisition of skills and abilities with the new harvest system (although the use of the tool is easily understood by collectors, this represents a strong variation compared to the traditional way of harvesting).

Figure 5 shows the favorable change in percentage of harvested immature coffee with the Alfa device over the course of the workdays. With time, the collectors developed greater skills in handling the equipment, generating greater confidence in its use. From the second day of work, the percentages of immature coffee lowered, reaching values very close to the recommended maximum.

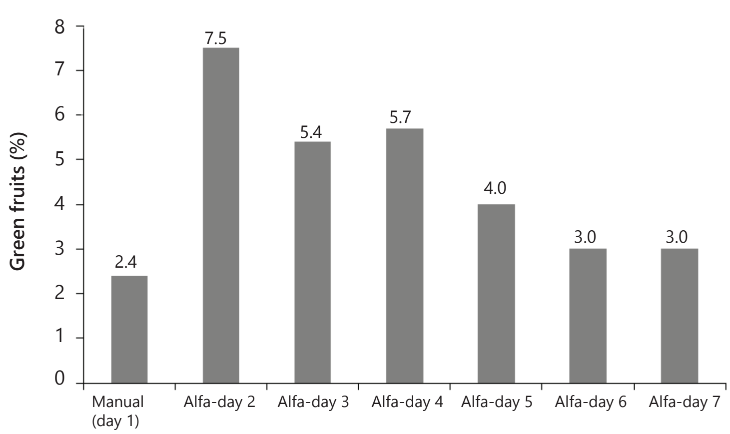

Figure 5. Immature coffee fruits present in the mass harvested with the Alfa device and manual gathering systems.

Yield. On each harvest day with the Alfa device, the collectors were able to increase their yield as compared to that obtained with the traditional method, reaching a maximum on the last day of harvest (the seventh day) with a value close to 25%. Figure 6 shows the favorable change in yield and the increase in yield for both the pairs and the individuals, possibly due to the strengthening of abilities and skills in the use of the harvesting equipment.

Guayabo Negro farm. In this case, the available mature coffee per tree was 1300 g, almost double that present during the evaluation at the Naranjal station in 2007; this reflects the typical mature coffee

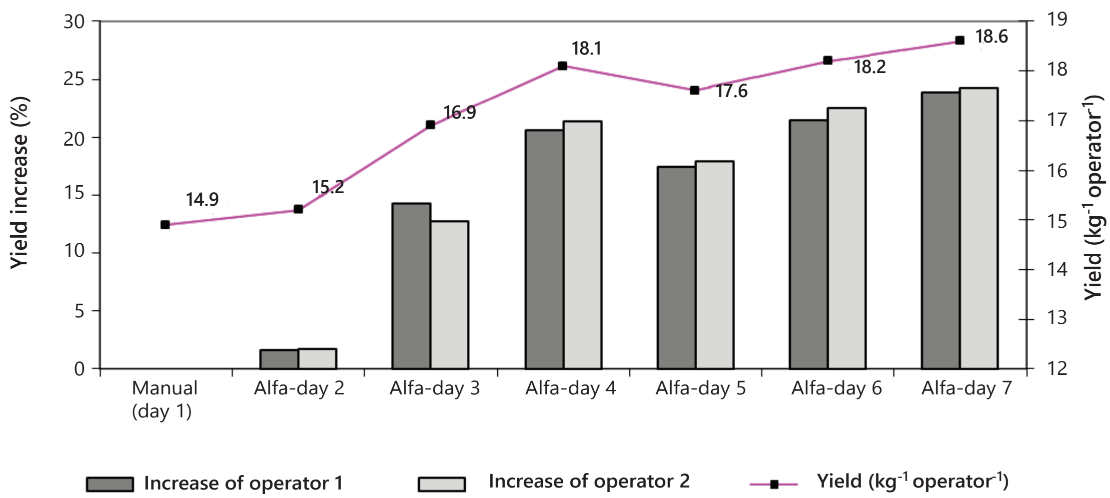

Figure 6. Coffee yield and increase of operator yield activity with the Alfa device and manual gathering systems.

offering in the region of southern Colombia during the principal harvest. This has a direct effect on the yield of the operators, and so exceeded the value reached in the 2007 assessments. However, these conditions also favored manual collection, with the Alfa devices showing an increase in yield of 11.4%, lower than that of the 2007 assessment.

The average percentage of harvested immature coffee for both systems exceeded the maximum recommended value (2.5%; Puerta, 2000). The Alfa device result was slightly higher than for the manual method, similar to that obtained in the first evaluation in spite of having a greater supply of mature coffee in the trees. Losses were lower for the Alfa device than for the manual system (Table 1).

Pueblo Bello substation. The average amount of ripe coffee per site was 1100 g, similar to that presented in the second evaluation, a common amount in the northern Colombia coffee region at harvest time. The average yield with the Alfa device and manual system

Table 1. Coffee harvest results for the Alfa device and manual gathering systems, Guayabo Negro farm.

Method	Yield (kg h^{-1})	Yield increase (%)	Immature coffee in the harvested mass (%)	Losses (No. fruits / tree)
Alfa	19.5	11.4	4.5	3.0
Manual	17.5		3.0	9.7

was less than the first and second evaluations, largely due to the difficult topography of the lot which limited the working capacity of the collectors (presence of rocks and 80% slopes). However, the maximum increase in yield at harvest with the Alfa device with respect to the manual system was superior to that achieved in the previous evaluations (32.7%). After the first day of work, the quantity of harvested immature coffee in the harvested coffee was very similar in both gathering systems and slightly higher than the recommended maximum (Puerta, 2000). For the number of fruits left on the ground after harvest, the situation was different; in this case, the harvest for both the Alfa device and the manual method had values far above the recommended maximums (Bustillo, 2002), occasioned in the Alfa device by the difficulties experienced by the pairs when locating the canvas of the baskets under the tree foliage (Table 2).

Table 2. Coffee harvest results for the Alfa device and manual gathering systems, Pueblo Bello substation.

Workday	Method	Yield (kg h^{-1})	Yield increase (%)	Immature coffee in the harvested mass (%)	Losses (No. fruits / tree)
1	Alfa	13.6	11.5	4.4	17
	Manual	12.2		2.3	6
2	Alfa	14.1	30.6	2.7	13
	Manual	10.8		3.3	7
3	Alfa	14.6	32.7	3.0	10
	Manual	11.0		3.1	7

Catalina station. As for the quality of the harvested coffee (Figure 7) with the manual system, the average GHM value was slightly higher than the maximum recommended; for the harvest with the Alfa device, the values were above the recommended ones and those obtained in previous evaluations; possibly the Alfa device was used in nodes with a low presence of ripe fruit, ignoring the recommendations given. In such cases, the collectors should have used manual harvest with the improved method (Vélez *et al*., 1999); however, fearing a decrease in yield and therefore income, at times, this recommendation was not followed. For the number of fruits left on the ground, in both systems, the recommended maximum was exceeded, being higher with the use of the Alfa device and "Tico" basket with canvas. But as the days passed, the operators acquired greater skill in managing the fruit gathering system and the values steadily declined (Figure 8).

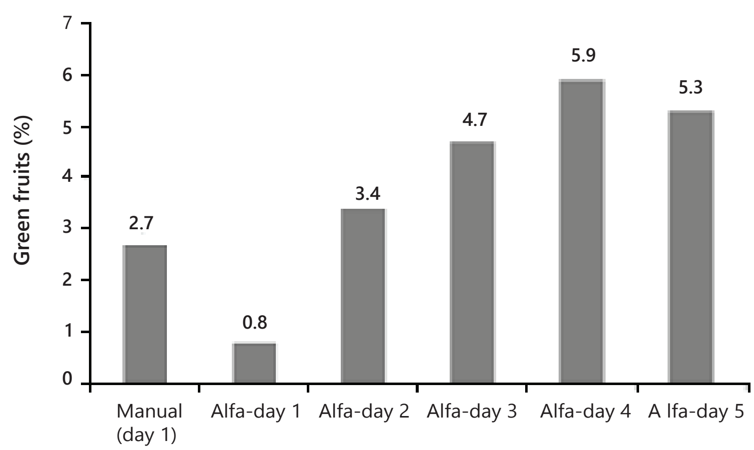

Figure 7. Harvest of immature coffee fruits with the Alfa device and manual gathering systems. Fourth evaluation.

The average amount of ripe coffee for the three lots was 1283 g, very close to that recorded in the second evaluation and remarkably high for the area. However, the average yield for the six pickers using the traditional manual method was the lowest recorded in the four evaluations. The yield for the first two days of harvest with the Alfa device was below the value recorded for manual collection, due to the learning curve for the new harvest system by the collectors; a situation that was

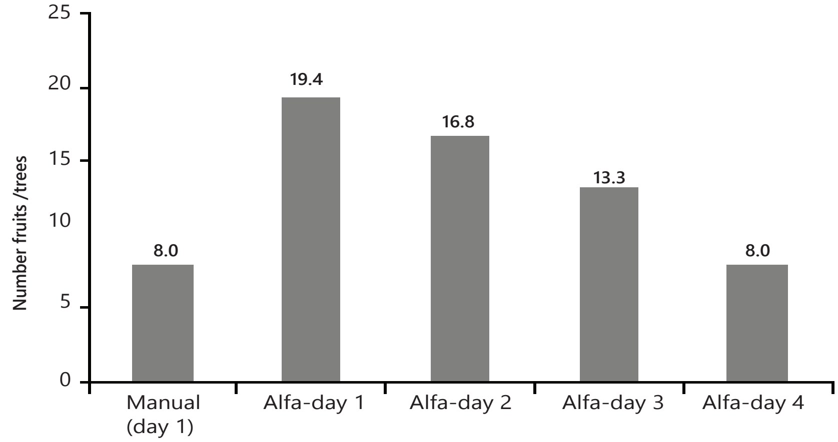

Figure 8. Losses of coffee fruits with the Alfa device and manual gathering systems, fourth evaluation.

seen in all the evaluations. Starting with the third day, the collectors were able to gradually increase yield when using the Alfa device, even reaching a value of 69% for the last day, the peak for the entire study (Figure 9); this coincides with a greater understanding and control of the equipment by the operators.

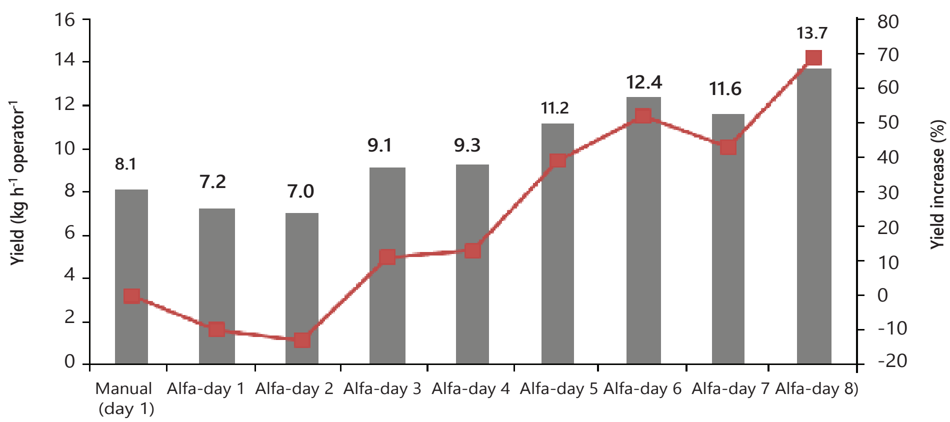

Figure 9. Coffee yield and increase of operator yield activity with the Alfa device and manual gathering systems. Fourth evaluation.

The results obtained during the evaluations over a period of four years led to identify that there was no physical discomfort for the operators who used the Alfa device or limitations to movement within the tested lots, which ranged from the first to fourth harvest, flat terrain to slopes of 80% and planting distances of from 1.5 x 1.5 m to 3 x 1m. The devices had no mechanical failures and presented operating times of 48 hours (6 days), which may favor battery life due to the number of recharges. Such features are very important when the aim is develop a portable device to assist the agricultural operations at the farms.

Finally, the results achieved for all evaluations showed that (see Table 3).

Losses. Average losses of coffee with both manual and Alpha equipment were statistically equal but exceeded the maximum value proposed by Bustillo (2002) for the integrated control of coffee berry borer, which is 5 fruits per tree. This result is similar to that reported by Martínez *et al*. (2005) in coffee harvesting with the traditional basket.

Immature fruits in the harvested mass. The average of immature fruits were statistically equal but greater than the maximum value recommended by Puerta (2000) to prevent damage of the beverage.

Yield. The performance with the Alpha device was greater than the obtained with the manual, but lower

Table 3. Overall harvest results with the Alfa device and manual system

	Losses (fruits/tree)		Green fruits (%)		Yield (kg h^{-1})	
	Manual	Alfa	Manual	Alfa	Manual	Alfa
Average	9.2	8.1	3.1	4.1	12.4	13.8
Standard deviation	4.2	6.8	0.8	1.7	3.3	4.1
Coefficient of variation (%)	46	83	27	41	27	30
Confidence interval	3.4	3.5	0.6	0.8	2.7	1.9
Lower limit	5.8	4.6	2.4	3.3	9.8	11.9
Upper limit	12.6	11.7	3.7	5.0	15.1	15.7

than the one reported by Oliveros *et al*. (2005) with similar equipment designed to detach fruits acting at glomerulus and plastic mesh beneath the trees to collect the detached fruits.

The device used to receive the detached fruits with Alfa, a plastic mesh extended on the top of a basket to direct the detached fruit into it, to increase the reception area, could have restricted the movement of the operator through the trees, affecting his performance, especially yield and losses of coffee on the ground.

CONCLUSIONS

While the Alfa device represented a substantial change in the method of harvesting, collecting with it was easy to understand, with only one day of training before starting the evaluations. Subsequently, the workers took a maximum of two days to increase their yield, which indicates that the operators easily adapted to its use.

The best results in losses of fruit left on the ground after harvesting were achieved with use of the modified Twin trays and when using the conventional basket with a poly-shade mesh extension (Mallacan). In both cases, the work was carried out on slopes of less than 20% and until the second harvest. When the basket with canvas was used on higher slopes and third and fourth harvests, losses exceeded the recommended maximums.

The percentage of immature coffee fruit with the manual system was always close to the recommended maximum. In the case of harvesting with the Alfa device, the highest values were recorded in the early days, consistently decreasing with the number of workdays, reaching values of 3%, very close to the desired value and one previously unreported with similar equipment. To the extent that the collectors generated skill and confidence with the device and that their yield and, therefore, income was not reduced with its use, they better identified the areas suitable for harvesting, working carefully without detriment to the work capacity.

In all the evaluations, it was possible to achieve higher yields with the Alfa device than with the manual system. With time, the collectors acquired skills for managing the device, steadily increasing yield with values close to 70%, results that have not been reported with similar devices. The harvesting method and use of the equipment were easily understood by the workers, and basic instructions and one day of training were sufficient to allow the collectors to quickly increase yield.

ACKNOWLEDGEMENTS

The authors wish to thank Cenicafé, the Universidad Nacional de Colombia and COLCIENCIAS project 2251-07-12086 for the support received during the present study.

BIBLIOGRAPHY

Bustillo, P.A. 2002. El manejo de cafetales y su relación con el control integrado de la broca del café en Colombia. Avance Técnico. Cenicafé 24 p.

Díaz, G.D., G.C. Ramírez, T.C. Oliveros y C.E. Moreno. 2009. Cosecha de café con el equipo STIHL SP-81 de actuadores oscilantes. Cenicafé 60(1): 41-57.

Federación Nacional de Cafeteros de Colombia (Federacafé). 2012. Costos de Producción de Café: Zona Central Cafetera. Gerencia Técnica. División de Producción y Desarrollo Social, Santa Fé de Bogotá. 13 p.

García, G.E. 2001. Estudios básicos prototipo italiano peine dinámico. Informe final ING 0134. "Cosechador Italiano TORDO y Peine Dinámico". Cenicafé. Colciencias, Chinchiná. 15 p.

García, G.E., M.F. Álvarez y T.C. Oliveros. 2001. Estudio experimental de la respuesta de la rama de café ante la aplicación de impacto mecánico. Revista Facultad Nacional de Agronomía Medellín 54(1-2): 1187-1209.

Martínez, R., R.E. Montoya, Z.J. Vélez, T.C. Oliveros, A.J. Buenaventura y U.J. Sanz. 2005. Estudio de tiempos y movimientos de la recolección manual del café en condiciones de alta pendiente. Cenicafé 56(1): 50-66.

Moreno, C.E., T.C. Oliveros, C.O. Alfonso and F.A. Mejía. 2013. Development of a new striker for a portable coffee harvesting tool. Revista Facultad Nacional de Agronomía 66(2): 7071-7083.

Oliveros, T.C. 1999. Evaluación de batidores mecánicos para la cosecha de café. Cenicafé. Informe anual de actividades. 26 p.

Oliveros, T.C. 2003. Evaluación de un vibrador portátil del tallo en la cosecha del café. Cenicafé. Informe anual de actividades. 59 p.

Oliveros, T.C., G.C. Ramírez, A.R. Acosta y M.F. Álvarez. 2005. Equipo portátil para asistir la cosecha manual de café. Revista Facultad Nacional de Agronomía. Medellín 58(2): 3003-3013.

Oliveros, T.C., V.J. Álvarez, G.C. Ramírez, U.J. Sanz, C.E. Moreno y M.A. Peñuela. 2006. Cosecha manual de café utilizando mallas plásticas. Avance Técnico, Cenicafé, Chinchiná. 354 p.

Oliveros, T.C., U.J. Sanz, G.C. Ramírez, C.E. Moreno y V.J. Álvarez. 2008. Evolución de tecnologías para la cosecha de café en investigación participativa. Informe final. Centro Nacional de Investigaciones de Café - Cenicafé, Chinchiná. 13 p.

Puerta, Q.G. 2000. Influencia de los granos de café cosechados verdes, en la calidad física y organoléptica de la bebida. Cenicafé 51(2): 136-150.

Ramírez, G.C., T.C. Oliveros, U.J. Sanz, A.R. Acosta y A.J. Buenaventura. 2006. Desgranador mecánico portátil para la cosecha del café. Descafé. Cenicafé 57(2): 122-131.

Vélez, Z.J., G.E. Montoya y T.C. Oliveros. 1999. Estudio de tiempos y movimientos para el mejoramiento de la cosecha manual del café. Avance Técnico. Cenicafé, Chinchiná. 21 p.

Vélez, Z.J., G.E. Montoya and T.C. Oliveros. 2002. Human factor performance in the coffee harvesting in Colombia. Ergonomics Australia 16(2): 14-24.