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Improving coffee production in small and medium farms in Veracruz, Mexico with the use of pneumatic equipment

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Abstract: Many coffee producing countries, including Mexico, are trying to introduce mechanization for this cultivation, in order to increase labor productivity levels and profitability. Mechanical assistance is particularly difficult during harvesting, indeed, differently from other crops, coffee plants have raceme flowers along branches, giving differing stages of fruit ripeness[1].

Manual labor can be combined with the use of small mechanical instruments, aimed at increasing productivity and limiting fatigue, the most interesting of which are scissors, chain saws and poles (driven by various energy sources) used for pruning and harvesting, which are the operations that require a greater amount of labor, particularly on sloping plantations.

This work describes the results of an appraised study of a compressed air tool for assisting coffee workers in the above-said operations.

After analyzing previous studies on similar equipment, field testing was undertaken on a particularly harsh mountainous terrain, the Mexican states of Veracruz and Chiapas, using Italian made products.

Keywords: coffee harvesting, mechanical harvesting, marginal areas, small mechanical equipment, portable tools, pneumatic tools

Introduction

Traditional varieties of coffee develop well in shaded scrub-land, protected from winds and with about 80% relative humidity. Very often these characteristics can be found on mountain slopes, which are usually the best areas for quality cultivation, but also the most difficult terrain.

In fact, even though manual labor for harvesting and other main operations is expensive, a valid alternative has not yet been found for these areas.

Completely manual harvesting is in any case the best way of assuring a quality product for graded ripening crops as coffee, even though in many coffee producing countries mechanization is seen as a valid remedy to the lack of manual labor and its costs. At the present, however, technology has not managed to substitute human skill[2]; moreover harvesting machines are generally not suited for rough terrain.

With manual labor, the operator does not strip the branches, but only selects ripe fruits inside the racemes, (which can have fruit at up to seven different ripening stages) and berries are picked by using forefinger and thumb, twisting the petiole. Harvesters obviously do not always limit their work only to mature berries (dark red or yellow according to the variety), but often pluck partially matured berries as well, to increase productivity, though still maintaining quality standards sufficiently high. (Bonaiuti, 2004). In some cases, whether due to operator negligence or technical choices, even green fruits are harvested, which badly damage the final product more than dry or fermented fruit (Puerta, 2000), thus in this case manual labor is not always synonymous with a quality product.

In steep areas harvesting is even more complicated with lengthy periods in covering terrain. The operator must proceed with caution, safely positioning himself near the plant to be harvested, reaching up for the higher branches; berries are put into a pouch and then, every 2 - 4 plants, the contents poured into a bag left at the end of each row. Coffee plantations usually slope between 100% to over 500% (45° - 80°), thus positions and movements, around and between the plants, are often difficult and slow. All this can take even longer if the plants are tall (as in local varieties such as *Typica*, *Criollo* and *Bourbon*, which are generally between 1.80 m and 2.50 m high) whereby the operator must have a hooked pole to use for bending the taller branches (figure 1). The larger the plantation is the less surplus time is lost.

As to the possibility of mechanizing farming operations in coffee plantations of this kind, and particularly harvesting[3], or only of simplifying manual labor (as in many cases it is no longer economically convenient)[4]; it must be considered that no concrete experience has as yet been established in this field as most resources have been aimed at mechanizing major specialized plantations found on plain land.

It has generally been considered that in other areas, the only usable forms of mechanization are based on the use of motorized equipment.

Many mechanized prototypes have been constructed over the years, but few have been used widely because of the above-said difficulties in just selecting ripe fruit like manual labor. Another obstacle for widespread mechanization in traditional plantations is the differing cropping systems. The parcels differ greatly in installation, variety, age, plant height and productivity, presence of shadow plants (and their density) and also for cultivation techniques (principally fertilization and pruning).

Suitable simple mechanical equipment now available for coffee harvesting is not specific, deriving from other sectors. The most interesting objects currently derive from the olive growing sector, which has for decades recognized the need of increasing harvesters' productivity, ergonomics and operational safety.

The principle upon which these machines are based is to accelerate the fruits in order to detach them from the branch with or without pedicle. This can be achieved with various techniques, albeit similar, differentiated by mode of vibration transmission.

Knocking down, which derives from rapping the fruit with a rod: it strikes the branches or directly the fruit with soft or hard elastic fingers: the finger movement is generally alternative and if done inexpertly can cause damage.

With the *shaker* the machine is hooked onto a wooden part of the plant, vibrating it.

This method often causes damages to the wood (Filgueiras *et al.*, 2000) and fails to transmit to the stalks the optimal frequency required for ripe fruit, about 450 Hz (Ciro, 2001); in any case the frequency is difficult to achieve practically: if lowered, the selective action is proportionately lowered. It is assumed that transmission of vibration from the trunk to the fruit depends on plant conditions (temperature, humidity, photo sanitary state etc.).[5]

The *raking* method is based on combs with differing teeth that go through the branches moving externally from the inside. It is hardly ever used as it often totally amputates the floral raceme, impeding successive years' flowering. The floral buds remain intact only if all the fruits in the raceme are mature because the force required for fruit removal is inferior to that required to remove the entire raceme. It is worth remembering that the most productive racemes are those furthest away on the branch, flowering sooner than closer ones; here the raking method is not so harmful, as when a floral bud is plucked it is generally an inner one, at the end of it productive cycle. This operation is handled manually with small metal or plastic combs or pliers with rubber rollers. These simple machines do not necessarily increase operative capacity, rather, they reduce the harvest strain and thanks to plastic or rubber appliances reduce fruit damage (Vieri *et al.*, 2001).

The *combing* method uses swinging combs whose fingers brush against the

Figure 1 - Manual harvest on greatly developed Typica plants

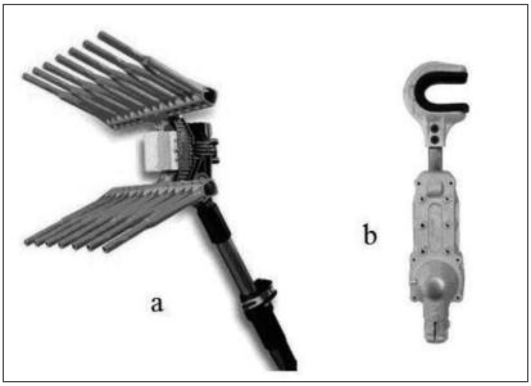

Figure 2 - Simplifying equipment for olive harvest: a. shaker hook, b. combing head

Figure 3 - Coffee plants in a typical Veracruz State establishment

fruit, initially from outside-in, then inside-out without breaking them off. This operation can have good results if undertaken properly; the operator must work lightly with floral buds, thus only removing the fruit with pedicle.

The light mechanized equipment used in the tests successively described is motorized and the heads are similar to those of the knockers but with closer fingers, like the combing method ones. These combs have a swinging movement and a beating or rapping action, which the operator manages according to needs; results are promising especially when compared to shakers, which vibrate all the plant without distinction. Simple and precise mechanized use gives a harvester the possibility of operating in areas of higher fruit ripeness.

In Mediterranean olive-growing areas these are surely the commonest form of equipment used since the sixties; indeed, the first models used for coffee harvesting came from Italy (Snoeck *et al.*, 1976).

Figure 2 shows 2 of the above described tools.

Other methods: there are other ways of harvesting coffee with simple manually carried equipment; for example, cherry suction instruments, capable of creating a cyclical vacuum detaching the fruits and blowing them into a basket (Campillo *et al.*, 2001), however, this has not found a practical outlet.

Many operational tests have been undertaken on light motorized tools for coffee harvesting, which are generally consist of an engine, movement transmission apparatus and handling rod with vibrating apparatus at one end.

In 1984 at the then Agricultural Mechanization Institute of Florence (today D.I.A.F.), a shaker applicable onto a motorized chain saw was patented, for harvesting juniper fruits. The handle had U-shaped pincers fixed at the tip of an alternately moving rod which vibrated at over 50 Hz with a width of 32 mm, but this action was too violent on coffee beans, damaging the plant and tiring the operator. The same institute subsequently tested a new rod shaker, derived from a trimmer, with a telescopic vibrant fitting, that was discreetly successful (Consumi, 1992). Later Zoli (Zoli *et al.*, 2000) resumed the chainsaw project, developing a coffee harvesting machine based on the shaker principle: this prototype also consisted of a hooked rod coupled to the chainsaw. The hook transmitted a continuous vibrating motion onto the plant facilitating the collection of about 90% of plant's fruit, in half or two-thirds of the time normally required. The machine's lack of selective capacity (the hook transmitted vibrations indistinctly to all branches), restricted its use only to plants with uniform fruit ripening sectors. Carvalho (Carvalho *et al.*, 2000), experimented a knocking pole with electric motor and combing head: in low plant output plantations the machine has not shown a great operative capacity, whilst it has been satisfactory with medium plant output, at least 5.45 kg of ripe fruit per plant. Research carried out by the same authors has shown that the percentage of fallen leaves is insignificant, and that the increased vibration frequency does not increase harvesting speed. Even in this case, the machine is not selective, but vibration is limited to the external areas, so at least the comb can be directed towards ripe fruits, avoiding unripe ones.

Others have experimented instead a shaking system attached to a small tractor, capable of swaying the entire plant with pliers formed by two rubber cylinders that seize the trunk at about 0.4 m from the ground. Because of limited plant damage this method is interesting, though not altogether feasible as it is aimed specifically to young recumbent plants of lower varieties with single trunk, and a maximum slant of 60%. Moreover, this machine also lacks selective capacity.

Other marginal coffee harvesting mechanization attempts have been made by farmers or enthusiastic technicians, but no actual method compares to manual harvesting, thus the incentive remains to continue research and experimentation.

With the aim of contributing to making coffee harvesting in marginal areas more productive, Authors have carried out work tests using olive pneumatic equipment constructed in a specialized Italian firm. The possibility of driving a wide range of tools has permitted to direct interest onto improving crop operations as well as onto harvest quality. Possibility of cost reduction on cropping operations, whilst still maintaining quality levels, allows farmers to increase economical outputs of their activity, thus reinvesting in the same plantations. Other neglected operations can be invigorated with subsequent productivity and/or harvest efficiency increase.

Tests have been undertaken in the Mexican Republic because it is one of the major world coffee producers (5th ranking), and the sector is of great importance to the country's rural economy.

Coffee is cultivated mainly in Mexico's tropical strip, between 21° and 15° latitude north with an average annual temperature between 20°C and 35°C, with minimum averages of 15°C and maximum of 30°C. As in the rest of Central America the most cultivated areas are hillsides with altitudes between 700 and 1,500 m.

The typical Mexican farming unit is smaller than 2 ha, located in rough terrain (figure 3), where cultivation importance is not solely economical, but as previously said, also ecological (different plants are used for soil enrichment and erosion prevention) and demographical, for maintaining the population in these marginal areas.[6]

Veracruz, along with other five states (Chiapas, Oaxaca, Puebla, Guerrero and

Table 1 - Coffee growers and average cultivated area in Mexico

STATE	n. OF GROWERS	CULTIVATED SURFACE (ha)	AVG AREA PER GROWER (ha)
Chiapas	46,657	163,268	3.5
Veracruz	39,931	98,196	2.5
Oaxaca	30,016	103,326	3.4
Puebla	24,196	53,437	2.2
Guerrero	8,434	40,939	4.9
Hidalgo	22,823	44,117	1.9
S.Luis P.	15,580	30,908	2.0
Nayarit	2,985	16,636	5.6
Others*	3,330	9,516	2.9
Total	193,922	560,343	2.9

* Tabasco, Jalisco, Colima and Queretaro.

Hidalgo), produces 80% of Mexico's coffee, whilst the remaining 20% is produced in other six states. This sector employs about 190,000 farmers, more than 350,000 seasonal employees, their families and all the people involved in transforming and commercializing coffee. About three million Mexicans depend on coffee in some way (Debernardi, 2002). The average surface area per farm in the state of Veracruz is of 2.5 ha, against the 3.5 ha of Chiapas and the 4.9 ha of Guerrero as shown in Table 1 (INMECAFE, 1991, CMC, 1999).

In Mexico, as in other countries such as Colombia, harvesting is traditionally carried out in four phases, with a 15 day lapse between each stage, thus only plucking ideally ripened fruit. This is a positive aspect of the Mexican production, differing from other countries where mechanization of large allotments is common and harvesting is done once only, resulting in a varied, low quality product because of mixing green, ripe, fermented and dried fruits.

Coffee Harvesting with Pneumatic Knocking Pole

Materials and Methods

Tests have been undertaken in Veracruz State, both on experimental parcels, (Collegio de Post-Graduados, Campus Cordoba and Sociedad Catuai Amarillo-Chocaman), which has easily accessible plain land, and also on typical commercial plantation allotments, that is to say rough, sloping forest terrain (private establishments at Tenejapa e Chocaman).

Table 2 - Cultivars and layout in the plantations n test establishments

LOCATION	VARIETIES AND CHARACTERISTICS	LAYOUT RANGE (m)	DENSITY RANGE (plants/ha)
Campus Cordoba Sociedad Catuaì Amarillo	Improved (yeld ad resistance) plants Piante a portamento basso, migliorate per produttività e resistenza alla ruggine: *Costa Rica 95*, *Colombia*, *Oro azteca*	1.5 x 1 2 x 2	6,666 2,500
Private farms in Tenejapa and Chocaman	Native Piante di portamento alto, rustiche,: *Criollo* or *Typica*, *Bourbon*	2.5 x 2.5	1,600
Private farms in Chocaman	Piante di portamento basso, non migliorate: *Caturra rojo* and *amarillo*, *Pacamara*, *Garnica F5*, *Garnica Iquimite*, *Batie*	2 x 2 2.5 x 2	2,500 2,000

These plantations differed for altitude, variable between 700 and 1,500 m above sea level, varieties, layout, plant height, amount of fruit per plant and harvesting period: these characteristics were considered particularly important during experimentation.

The simplified mechanical equipment was tested on the following *C. arabica* varieties:, *Caturra rojo*, *Caturra amarillo*, *Pacamara*, *Garnica F5*, *Garnica Iquimite*, *Colombia brote verde*, Colomb*ia brote cafè*, *Costarica 95*, *Oro atzeca*, *Tipica*, *Bourbon* and *Batie*. The characteristics of the plantations where trials were done are shown in Table 2.

Particular attention was paid to plant height, which ranged between 1.5 m and 2.5m, as it was believed that it could influence fruit falling trajectories. The amount of fruit per plant depends on variety, altitude, cultivation layout and, above all, on the crop tending operations (fertilizing, pruning etc.).

As regards to harvesting, with reference to the traditional four phases, the first and last passages are those in which least fruit is collected with higher time loss that can lead up to 30% reduction in operative capacity. The harvesting tests have been done in correspondence to the two central phases.

An analysis of the plantation was carried out in every selected area, thus highlighting prevailing varieties, average plant age, phyto-sanitary state and terrain slope. The typical plants to be tested (10 minimum), were chosen from the plantation following the four cardinal directions and at the centre of each allotment. For each plant the test included observations on the following operations: positioning of engine-compressor group, equipment connection, spreading of the fruit collecting sheet and harvesting; time was measured for each operation.

Measures and surveys were carried out using simple instruments such as dynamometer, calliper, chronometer, GPS receiver and digital camera. Information was collected and processed directly on site, using a portable computer: thanks to this an optimized work progress was guaranteed.

Amongst the simplified mechanical equipment considered eligible for coffee plantation operations, were the pneumatic instruments, considered versatile because lightweight for manual use, autonomous and reasonably priced. The vibrating comb machine (Campagnola s.r.l. - Bologna, Italy[7]), was considered a particularly valid instrument for this kind of work.

The system (Figure 4) consists of an engine, a compressor, and of a vibrating comb apparatus. The compressor (Campagnola 5830 model) has a 490 l/min capacity and is equipped with an air tank of 8 l; it is driven by a petrol engine (Honda GX 160 5.5, 250 cm^3, 4kW), with 2 hour autonomy (average consumption 1.25 l/h). The vibrating combing apparatus (Campagnola Samba model) weighs 1.5 kg and is composed of two combs with 4 teeth each, swaying on parallel axis, with a symmetrically opposing movement, mounted onto an aluminium telescopic rod, (length 1.25 - 1.95 m, weight 1.3 kg); they are activated by a small engine that works at an 8 bar pressure and 200 l/min capacity. The apparatus is connected to the air tank via a pneumatic polyurethane hose with elliptic section (8 mm x 10 mm) in a 50 m skein with rapid clutches at the tips. The system is capable of driving two vibrating comb heads plus one pneumatic scissor.

The advantage of using such instruments is their lightweight and the fact that vibration, noise and exhaust fumes are concentrated near the engine, far away from the operator. The operator thus works with less fatigue, is more productive and can concentrate on selecting plant areas with riper fruit.

Even comparing the pneumatic system to those based on electric engines and battery-powered, it still remains lighter for the operator and has greater autonomy since the petrol engine can be continuously refuelled.

From a productivity point of view the system behaves like a mobile powering unit as the pneumatic force produced can move a whole series of instruments that can be used for most operations required by coffee and also from other plants (bananas, avocados, macadamia) that can be found on the plantation. The air pipe connected by rapid clutches makes the changing of tools very easy and fast.

However the tools are connected to the compressor by the hose which hinders movement, reducing single operator autonomy, the system transport can be complicated on rough terrain and its operation is noisy and polluting (albeit being placed away from operators it can be tolerated better than other hand tools driven by endothermic engines, especially two strokes).

The parameters tested using the combing system were vibration frequency (number of strikes per second), application time (minutes) and application direction (orthogonal, parallel or oblique) (Martinez *et al.*, 1989).

As for olive harvesting, together with the knocking pole, a sheet is used for fruit collection, which facilitates harvesting operations thus avoiding direct contact of fruits with earth (Figure 5).

Initially a circular sheet was used (Ø 2,5 m), but this did not completely cover a row, so, to avoid upsetting and consequently wasting time, a bigger rectangular sheet was designed (3 m x 2.5 m), which completely covered the ground.

The sheet was initially made out of PVC, but this material is too stiff hence difficult to place and unable to adapt on the spontaneous vegetation found under the coffee plants, even if the thickness was reduced or a net was used in place of the sheet. A cotton sheet was then used, which is environmentally easier to dispose of. Strips of Velcro were then applied to the sheet to improve positioning, closing and moving it from one place to the other and, after initial tests (on tall coffee varieties in particularly rough forest terrain); hooks were then added to the corners for anchoring onto nearby plants. Opposite to the Velcro strips area a sack was attached for fruit collection when repositioning was required. The idea of a sack came after observing manual harvest, which is normally done with a small basket hooked onto the harvester's belt, which can contain about 5 kg of coffee. Once full (2 plants are usually needed for this), its contents are thrown into a PVC sack found at the end of a row.

The sack's opening was protected by a net to avoid bigger objects falling in (e.g. leaves), making later selection easier.

The system weighed a total of 85 kg, and was transported to the different sites on a pick-up truck; the work team consisted of 3 people.

The first aim of the work was to compare manual harvesting time to that of the pneumatic knocking pole system; if greater operational capacity of the machine was shown, then the other parameters would be considered for quality comparison:

- green fruit percent
- amount of leafs
- amount of peduncles

Figure 4 - Pneumatic equipment for coffee harvesting and other operations

Figure 5 - Fruit collecting sheet with sack

Figure 6 - Coffee fruits shaked off the tree and collected on the sheet

All these parameters would then be related to harvesting time, vibration frequency and pedo-climatic conditions to gauge any influence and to identify the best harvesting conditions with the use of the mechanical system.

Subsequently, tests would be repeated on different coffee varieties and different plantations, to highlight any conditions that could influence the use of the system.

The possibility of using this system together with other pneumatic instruments, in coffee and other cultivations, would also be considered.

Harvesting tests

Harvesting tests were carried out manually and with the pneumatic equipment on 13 coffee varieties with 4 different plantation patterns at three of the four ripening stages considered fit for harvesting. Each test was repeated five times, measuring the time and successively considering the quality of the work.

A count was also kept of fruits with peduncle for the most common variety (*Typica*).

The first test was undertaken on the experimental camp at the Post Graduate College, where the equipment was set up, whilst the others were done at the above-quoted farms (previous paragraph), in order to consider all the problems deriving from difficult working conditions.

The collected fruits (figure 6), were separated from debris (which was also weighted), and divided into seven classes according ripeness: green, yellow (30% ripe), 'pinton' (50% ripe), light red (80% ripe), ripe (100% ripeness), fermented and dry. Also the number of collected fruits witch still had the peduncle attached was recorded. Also all the fruits that had remained on the plant were counted and classified according to ripeness. Particular attention was given to undetached green and yellow fruits and to the ripe ones that were hand picked measuring the time.

When harvesting with the pneumatic equipment, also fruits found outside the collecting sheet were counted and classified to test sheet efficiency, dividing them into the same above-quoted classes and weighting them. Extra time required for positioning and removing the sheet under the plants (figure 7) was also taken in account and after the tests, each plant was examined for any possible damage.

The equipment was tested also in extremely difficult situations, were certain operational limits surfaced, however improvements seem possible without incurring major changes. Engine fuelling drawbacks on steep slope were seen: carburetion apparatus change is recommended so as to avoid faults in rough terrain. Tests were also undertaken on the three commonest varieties (*Typica*,

Figure 7 - Harvesingt post in the estate of Roberto Escamilla, Chocaman, State of Veracruz

Figure 8 - Pruning of a coffee plant with pneumatic scissors on pole

Bourbon, *Colombia*), cultivated in the same layout (2 m x 2 m), at different altitudes to see any eventualities connected to the altitude.

Results

Data on operative capacity of the equipment relates only to the marketable part of the harvested fruits, that is to say only to the ripe fruits that were collected and not to all what was harvested.

In the trials undertaken on the private plantations manual harvest capacity varied between 54.7 and 86.4 kg per man working day (8 h), whilst the mechanically aided harvest capacity ranged between 109.4 and 262 kg per post per day, thus between 54.7 and 131 kg per man day since a post was composed of two people[8]. In tests undertaken on experimental allotments with ripe 3 year old plants, well attended, pruned and fertilized, results were far better, with work capacity ranging between 184.3 and 921.6 kg per post per day. These values are impossible to achieve on most of the plantations of the region because of allotment layout, cropping technique and phyto-sanitary conditions.

As far as fruit ripening stage is concerned, 5 to 32.4% of unripe fruit ware collected with manual harvesting and 59 % with the mechanical equipment. Of manually harvested unripe fruits 80.7% still had the peduncle against 33% of the mechanically harvested ones.

The sheet missed 12% of fallen fruit, 79% of which were productively eligible.

Other harvesting alternatives, such as the scissors with applied compressors, chainsaws and branch-cutters have been tested with encouraging quality work results, although no specific measurements have been undertaken (figure 8).

Discussion

The tests undertaken on typical establishments have shown a harvesting operative capacity with simplified mechanical equipment, ranging from 1.5 (plantation) to 5 (experimental parcels) times greater than manual harvesting.

For greater efficiency in mechanical harvesting, plant shape must be observed, so as to shake the secondary branches or racemes only, where the majority of ripe fruit grow. The shaking head should shake ripe fruit off without damaging the plant's productive structure and without striking unripe fruit, if a second harvest will follow. Leaving green fruits on the plants is however unhealthy so, if only one harvest is planned, it is somehow better to remove green fruits also, even if the following sorting operation will be longer. With mechanical equipment use, larger amounts of green fruit do fall, but this data only highlights any eventual seasonal harvesting loss, and not any future plant productivity damage.

With this in mind the percentage of fruit with peduncle is important, as the loss of peduncles reduces the following years' production. For this reason the amount of green fruits collected is not as important as the number of peduncles. Mechanical use certainly causes more green fruit fall, albeit shaken off rather than torn off as in manual harvesting. With the latter harvest, it is possible to detach a very low number of peduncles by twisting rather than tearing the fruit off, however this operation is slow and employees are paid by the piece making this special attention rare.

Subsequent green and ripe fruit separation can be done during immersion in water for washing (the first float, the second do not), this is a good practice for removing any dirt and debris before eliminating fruit flesh, although harvesters often overlook this phase, due to high confidence I the quality of their work, especially when the same harvesters are in charge of the washing.

The sheet resulted too small and should be redesigned, keeping in mind the need to clear the soil before positioning it to avoid large and deep creases that disturb the collection of the fruits,

The engine-compressor group is not easy to handle on slopes; in fact, difficulty in finding the correct engine placing has led to flooding and stopping. The under carriage ground clearance is insufficient so transport is difficult because of waste, stones and plant debris. The spark plug position makes disassembling difficult.[9]

The knocking pole head cannot be rotated 180° for easy entry into the vegetation and the pneumatic hose is too rigid and hinders movements.

Conclusions

The work undertaken has shown the possibility of introducing an intermediate level of mechanisation for coffee pruning and harvesting operations, even in mountainous areas. Obviously the use of vibrating comb machines for harvesting hilly allotments cannot be compared to the use of specialised equipment in plain land plantations, where work is continuous. Yet again, the dilemma is whether it is worthwhile cultivating in certain areas which obviously guarantee a superior quality product, but also have higher running costs; the question is open for coffee, as in many other cultivations. Unfortunately the socio-economical advantages, first of all the potential employment interest of these situations, do not always match with the global market logic, where small productions of higher quality are not appreciated. Thus, only the 'cafeteros' can plan a better management, knowing the cost profit relationship.

The authors have suggested an organisational model which can improve use of manpower which even in the 'Sierra' of Veracruz State is nowadays difficult to find.

Notes

[1] 2-4 harvests of the same plant within 3 months are necessary for obtaining a quality product.
[2] Only in less demanding markets and favourable businesses can mechanisation supplant manpower.
[3] Harvest analysis has been chosen after monitoring the entire chain process: this is the only way of understanding and improving weaknesses; compartmental analysis instead overlooks many problems connected to other different phases.
[4] Apart from the previously described problems, product quality is not always adequately compensated.
[5] Marginal area plantations in Central and South America are often old and untended, thus plants have growth lump malformation sprouting, with irregular development in fruit-bearing areas, thus vibration transmits differently reaching the fruits with different frequencies.
[6] Coffee cultivation also plays an important environmental role, especially if grown in rough terrain. If cultivation is maintained well in these areas, a permanent vegetative mantle forms, thus greatly reducing erosion which remains aggressive in other cultivations or unshaded coffee plantations - furthermore, until recently coffee remuneration was relatively high as regards other cultivations, giving local populations the possibility of living in rough terrain; thus with adequate coffee remuneration heavy urban emigration for employment leaving cultivations untended.
[7] Established in 1958 produces pruning and harvesting instruments and operates on a worldwide basis including tropical areas.
[8] The site was composed of three people, third person for field survey, counting un harvested fruit and computer work; the site would normally have 2 people, one for knocking fruit down and the other for positioning the sheet; in ideal sites where work organization is optimized and more knocking poles are used at the same time, the ratio between operators and work posts could fall to 1.5.
[9] Frequent cleaning is necessary because of low fuel quality and of imperfect combustion due to the above-said causes.

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