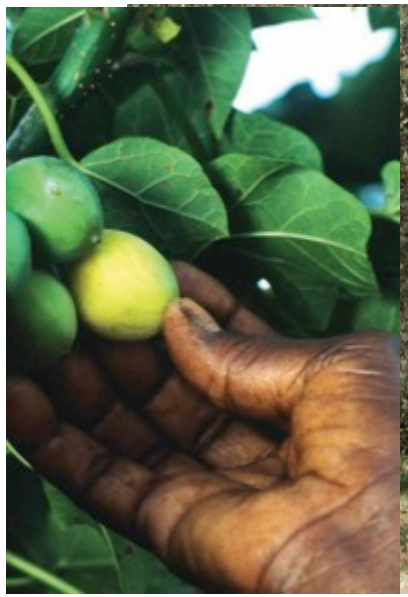
***JatroMed Project***

*Evaluation of the energy crop Jatropha curcas as a mean to promote renewable and sustainable energy for the Mediterranean region (JatroMed)*




# Workshop

**Marrakesh (MO), November 15th , 2013**

## State of the art on Jatropha curcas harvesting

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# Jatropha harvesting issue

Jatropha Fruits do not ripen together

Flowering and, therefore, fruiting are continuous, meaning that mature and immature fruits are together in the cluster, and in semi-arid regions such as North Africa, the harvesting is made during two months.

The harvesting require weekly picking and make the harvest very labor intensive and difficult to mechanize.

Low yield per hectare and small fruit size demands intensive labor and in relation to the hourly cost can be expensive.

# Variables that affect the harvesting

- Variety
- Climate
- Soil characteristics
- Plant height
- Plant spacing
- Row spacing
- Pruning
- Headlands
- Harvest date window
- Maintenance
- Field size
- Socio-economic aspect
- …

High variability should be take into account in order to define the best mechanization. The pictures show the effect of water and nutrient stress on two years old plant size (Andhra Pradesh, India) (FAO, 2010).


Jatropha with adequate water and nutrients.


Jatropha growing in dry marginal soils.

# Variables that affect the harvesting: Crop yield

Jatropha shows also a high variability in yield per unit surface in relation to water supply and soil fertility (FAO, 2010).

| Water supply | Soil Fertility | Dry Seeds (kg/ha/yr) |
|---|---|---|
| Optimal | high | 6,000 |
| | medium | 2,500 |
| | low | 750 |
| Normal | high | 3,500 |
| | medium | 1,500 |
| | low | 500 |
| Sub-optimal | high | 1,500 |
| | medium | 750 |
| | low | 250 |

**Expected Jatropha seed yields for different water supply and soil fertility (FAO, 2010)**

# Variables that affect the harvesting: Spacing and management

Jatropha is planted at different densities
2500 plants $ha^{-1}$ (2 m x 2m)
1600 plants $ha^{-1}$ (2.5 m x 2.5 m)
1111 plants $ha^{-1}$ (3 m x 3 m)

Spacing in plantations can vary and should be based on the environment. Yield per tree is likely to increase with wider spacing but with a decline in yield per ha (Achten, 2008).

**A commonly applied plant spacing in semi-arid, low-input systems should be in a rectangular pattern of 3,0 x 2,0 ; 3,0 x 2,5 or 3,0 x 3,0 meters (FAO, 2010).**

# Variables that affect the harvesting: Pruning

Plant cut back (FACT 2010)

- Pruning keep the plants in a manageable size

- Jatropha flowers form only at the end of branches, pruning leads to more branches and as such to more potential for fruit production.

- With good pruning the jatropha plants, in the fourth or fifth year after planting and after several rounds of pruning the plants should ultimately have some 200-250 terminal branches.

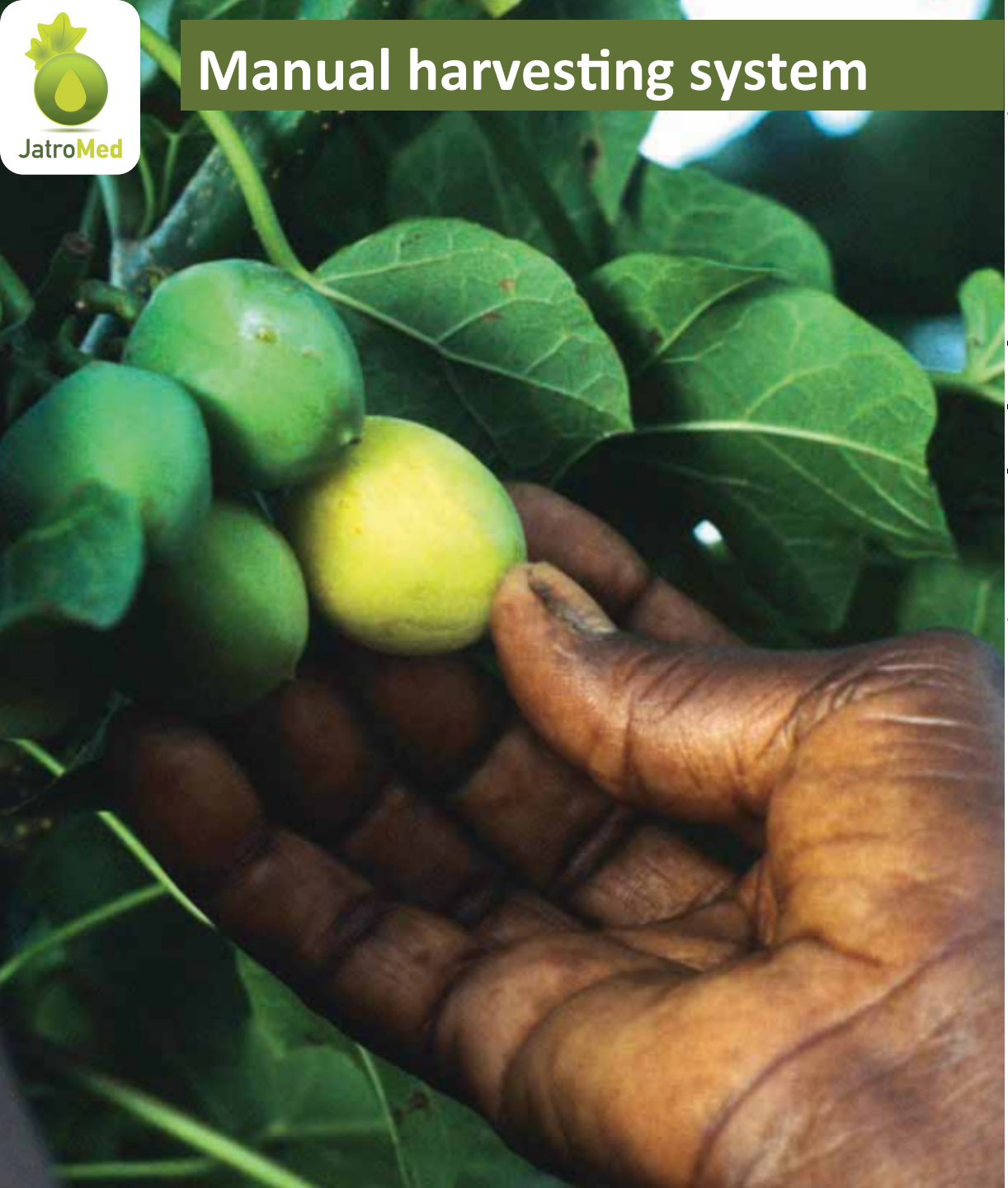
# Jatropha harvesting methods

1) Manual harvesting system

2) Semi-mechanized harvesting system

3) Full mechanized harvesting system

# Manual harvesting system



The yellow and brown fruits are harvested by hand picking or beating the branches with sticks to knock them to the ground.

The fruits are dried and the seeds removed from the fruit shells by hand, by crushing with a wooden board or by using a mechanical de-huller.

# Manual harvesting system

Past projects data highlight that there is a large variation in picking efficiency (FACT, 2007)

Wild stands: 20-30 kg per person per day

Well-managed plantations: 40-70 kg per person per day

# Manual harvesting system

**Pros:**

- cheap;
- no maintenance;
- selective harvesting.

**Cons:**

- It is labor intensive work;
- It is time consuming relative to the amount of oil produced (with 50 kg in average per person per day) ;
- ethically questionable – availability of cheap enough labor may be the most important factor for having a viable, decentralized energy solution (Grimsby L K et al., 2012) using hand picking harvesting.

# Semi-mechanized beating/shaker harvesting system

These machines are carried by the operator and applied directly to the canopy. They are mounted on long handles up to 2–3 m in length and driven by 12–24 V electric engines, compressed air or small endothermic engines. It is possible to identify two main groups of devices:

-*Pneumatic/electromechanical hand carried pickers based on a **beating** harvesting system*




- *Mechanical/Pneumatic hand-carried **shaker**.*


# Semi-mechanized beating harvesting system

**Hand carried pickers based on <u>beating system</u>: theoretical application to the jatropha fruits**

The cluster of Jatropha fruits should be beaten from the bottom or shaked between the rakes.
Therefore the rape fruits fall below onto a waiting net.

Tests will be necessary to verify the applicability and the performance of the harvesting system, and to optimize the rakes speed (strokes per minute) in order to dropping only ripe fruits.

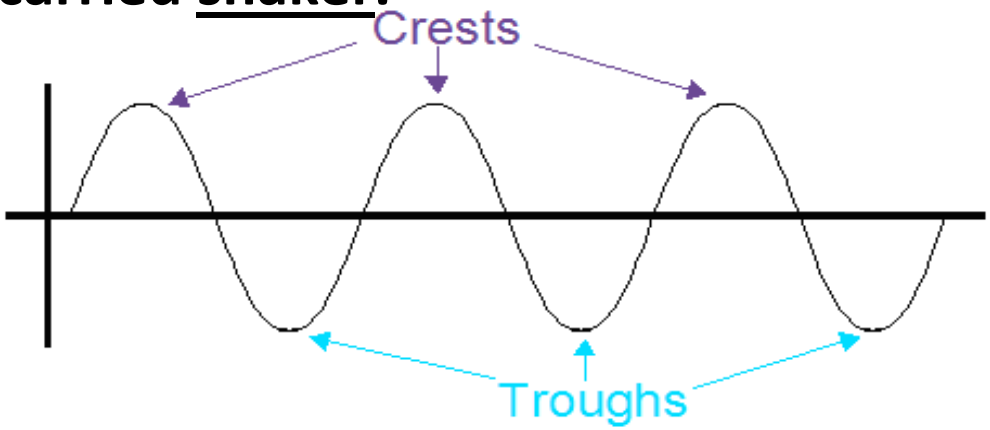
# Semi-mechanized beating harvesting system

**Hand carried pickers based on beating system: harvesting of Argan's fruits first experiences**

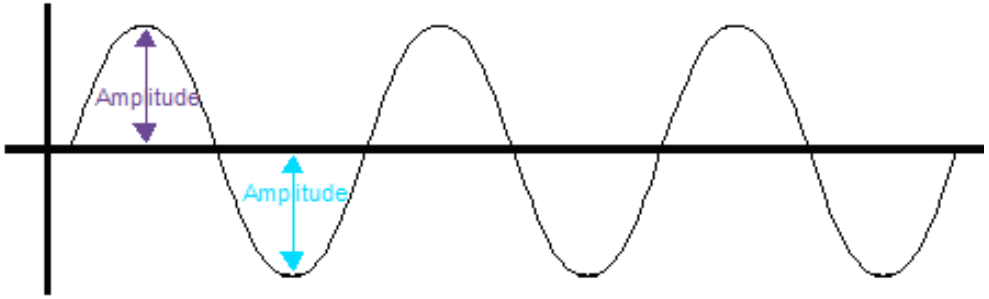
# Semi-mechanized shaker harvesting system

## Mechanical/Pneumatic hand-carried shaker.

Machinery which produces vibrations causes torsion in addition to traction and flexion. Shaker generates vibrations with a variable **frequency** (Hz) and an **amplitude** or stroke (mm). The fruit is dislodged when effective combinations of frequency and stroke generate sufficient acceleration to detach the fruits, which is achieved more easily with resonance frequencies of the system.



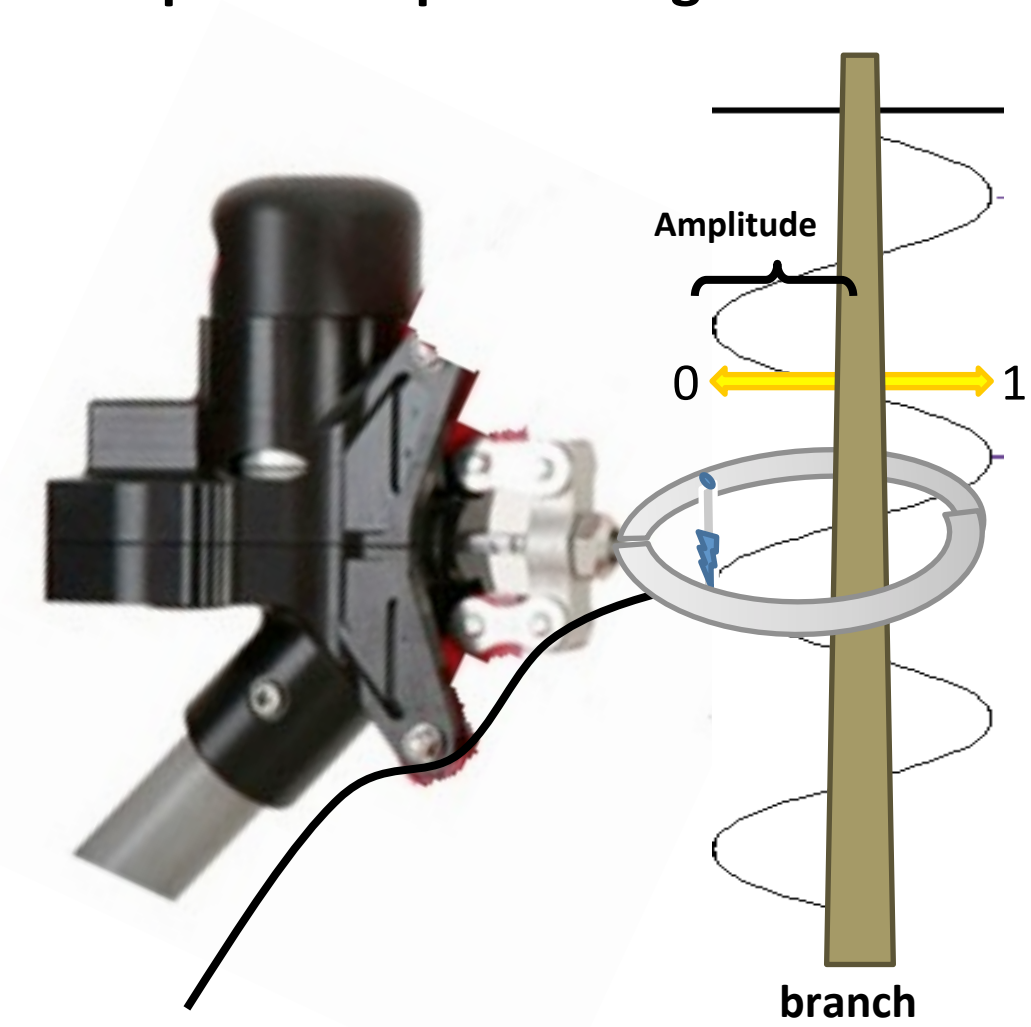

- **Frequency** is a measurement of how many cycles can happen in a certain amount of time (cycles per second).
- Hertz is the unit of frequency, and just means how many cycles per second (Hz).




- **Amplitude** is a measure of how big the wave is.
- It takes more energy to make a bigger amplitude wave.
- The amplitude of a wave is measured as: the height from the equilibrium point to the highest point of a crest or the depth from the equilibrium point to the lowest point of a trough

# Semi-mechanized shaker harvesting system

## Range of frequencies and amplitudes required to drop down only the ripe fruits: pioneering studies




**Minyoung Hong. 2012**. Study of a Harvesting Mechanization Method for Jatropha Curcas L. Using Nonlinear Optimization. Proquest, Umi Dissertation Publishing. EAN: 9781249847687

**The global optimal solution founded:**
**A:6.43 cm – F: 2.2 Hz**
**(G:3% - Y:68% - B: 74%)**

Mohd Rokli Hizra **Ramli,** Mohd Noor Abdul Ghani, Mohd Hudzari Razali, Fazlil Ilahi Abdul Wahab and Norhayati Ngah. **2012.** Determination of vibration properties of Jatropha curcas for mechanical harvesting operations. Songklanakarin J. Sci. Technol. 34 (1), 9-15.

**F: 1.4 Hz to 6.48 Hz**
**A: 2.5 cm to 5.5 cm**

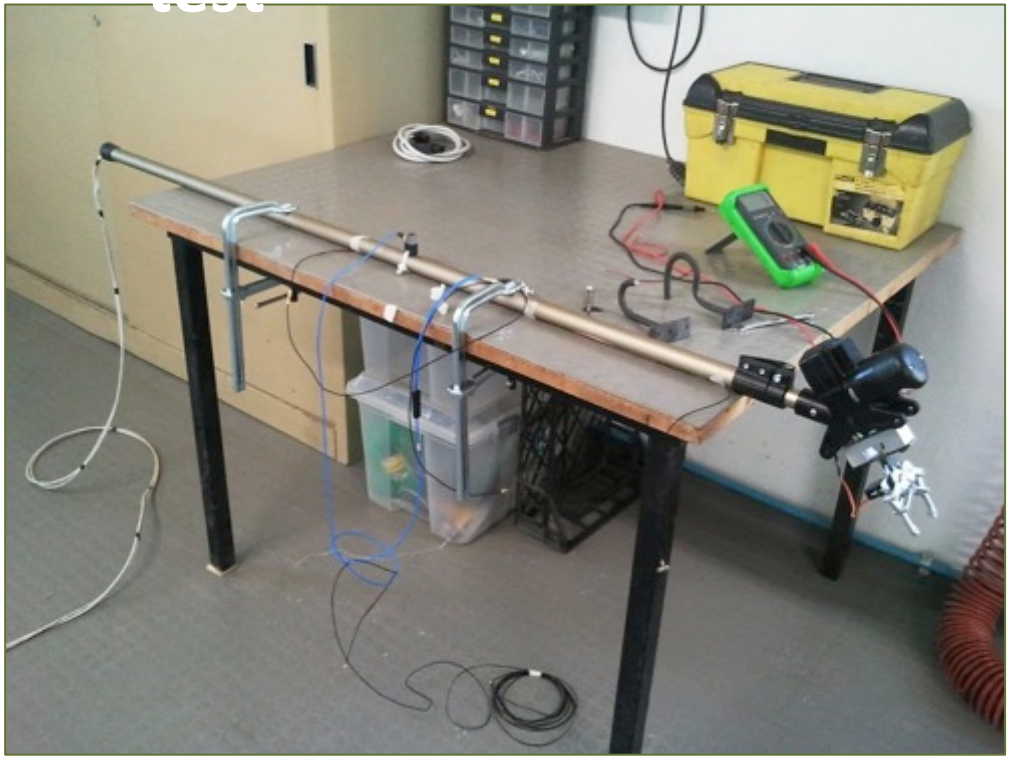
# Semi-mechanized shaker harvesting system

**Range of frequencies and amplitudes required to drop down only the ripe fruits: some considerations**

- There is the need to identify the appropriate amplitude and frequency in order to detach only the mature fruit without dropping the unripe fruit in relation to the variable factors, such as:
  - -Diameter of twig;
  - -Length of fruit stalk;
  - -Ripening stage of fruits;
  - -Position of fruit in the fruit cluster;

-Shaking point of the same branch does not really influence the frequency used (therefore the vibration can be applied to any part of the appropriate branch);

# Semi-mechanized shaker harvesting system: CRA-ING – device modification and laboratory



Tests in CRA ING Lab

# Semi-mechanized shaker harvesting system: CRA-ING Preliminary Field tests in Agadir, Morocco (22-26 October, 2012)

# Semi-mechanized shaker harvesting system

## CRA-ING preliminary jatropha harvesting test in Morocco

### Morphologic parameters observed

| | Mean | Min | Max |
|---|---|---|---|
| | | | |
| Plant height (m) | 185,0 | 160 | 210 |
| Trunk diameter (mm) | 81,4 | 31 | 99 |
| Branch diameter | | | |
| *Distal to the bunch* (mm) | 11,9 | 9,45 | 16,14 |
| *Proximal to the bunch* (mm) | 9,9 | 8,59 | 11,08 |
| Bunches per plant (n) | 12,0 | 2 | 27 |
| Fruits per bunch (n) | 3,0 | 1 | 17 |

### Fruit detachment force (FDF) and its ratio with fruit weight

| | Fruit | | | | | |
|---|---|---|---|---|---|---|
| | Unripe | | | Ripe | | |
| | mean | max | min | mean | max | min |
| FDF (N) | 14,5 | 23,2 | 4,6 | 11,5 | 20,6 | 2,4 |
| FDF $W^{-1}$ ($N\ g^{-1}$) | 2,54 | | | 1,17 | | |

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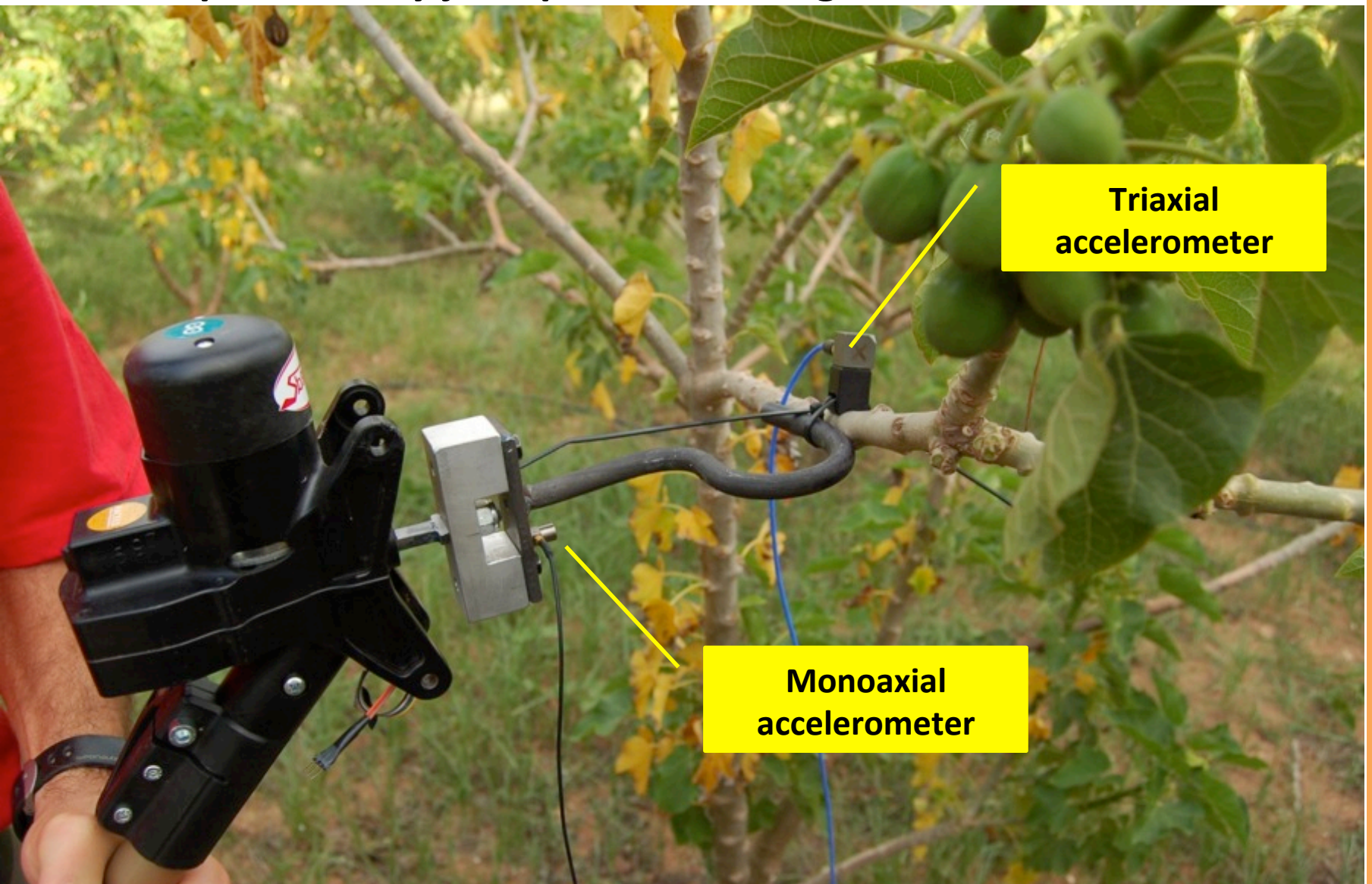
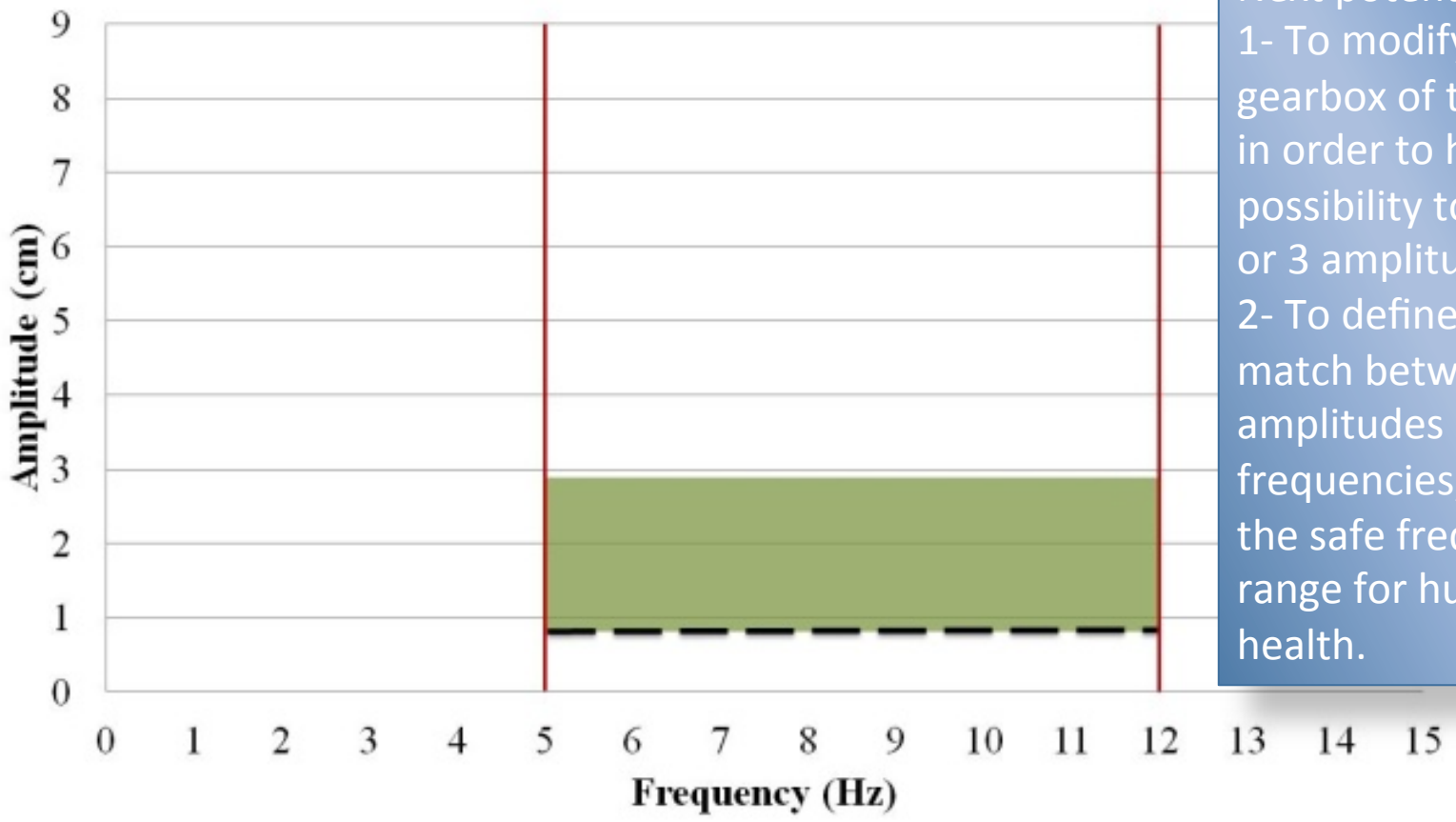
# Semi-mechanized shaker harvesting system

## CRA-ING preliminary jatropha harvesting test in Morocco



# Semi-mechanized harvesting system

## CRA-ING preliminary jatropha shaker harvesting test: results and next potential test




Next potential test:
1- To modify the gearbox of the device in order to have the possibility to chose 2 or 3 amplitudes.
2- To define the best match between amplitudes and frequencies, within the safe frequency range for human health.

**Figure**: relationship between amplitude (cm) and frequency (Hz). The red vertical lines represent the frequencies limits safe for worker health; the dotted black line is the level of amplitude and frequencies tested in the present study; the green box is the area of amplitude x frequencies combination that will be analyzed in the further tests.

# Semi-mechanized harvesting system

**Fruits collection: net or bag-a-nut harvesting machine**

Nets need to be used to catch and hold the fruit (as for olive trees).
In alternative is possible to use nut rollers harvesting machine.

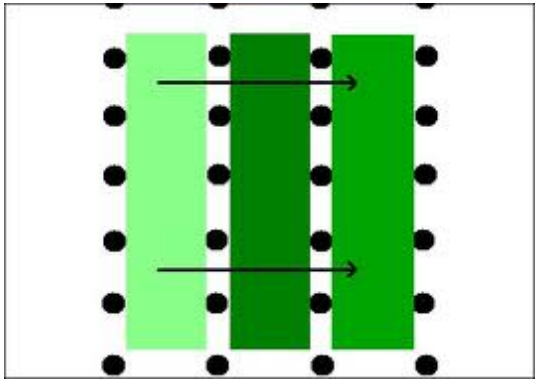
# Fruits transportation

Providing pickers with a chariot on which to move through the bush lines would increase the performance and reduce the intensity of manual picking.

The chariot can be drawn by a two-wheel tractor which is a good option due to the low cost, low maintenance and high versatility .

# Semi-mechanized harvesting system

1° group of work
(two people move the net)



2° group of work
(two/four people to harvest)

3° group of work

(One/two people for driving, and de-hulling the fruits directly in the field using the PTO of the tractor, leaving the shells on the field)

# Semi-mechanized harvesting system

**Pros:**

- low investment requested;
- low maintenance level;
- adaptability to various orchard layout;
- reduced of labor fatigue compared with hand picking;
- Increment of about 3 or 4 times the hourly work rate compared with hand harvesting (in case of olive grove);
-the possibility to be equipped with other types of implements (saw and cutters for pruning);
- the possibility to be used to harvest other fruit orchard (Argan, Jojoba, olives).

**Cons:**

- adapt for small surfaces;
- less selective harvesting compare to manual

# Full mechanized harvesting system

Full mechanized harvesting systems can be of interest whenever 250 – 300 ha per years have to be harvested and in the case of high labor costs or labor lacks.

## -Over-the-Row Harvesters:

These types of harvesters are based on the **adaptations of grape or coffee harvesters** with **horizontal shaker systems** equipped with horizontally pivoting arms which **smack the canopy, or vibrating fingers** which dislodge clusters and berries from clusters. These can be **self-propelled or towed**.

## -Inertia trunk shakers:

**Vibrating shaker** with a shaft fitted with stiff radial rods and rotating eccentric masses which **generate high-frequency vibrations**, that are conduct from where the machine grips the tree to the point of the fruit attachment .

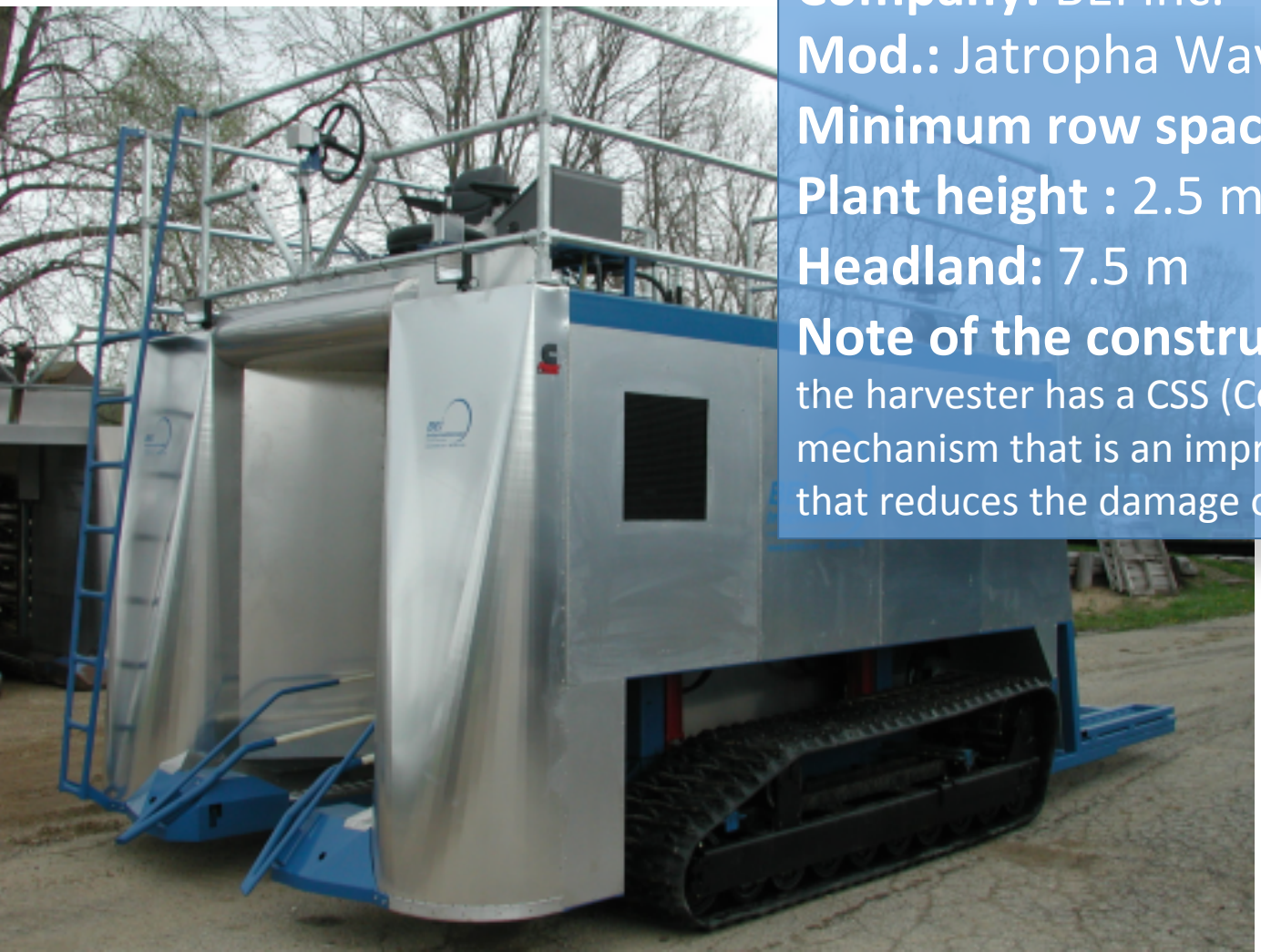
# Full mechanized harvesting system: Over-the-Row Harvesters

## Modified Coffee Harvester


**Company:** OXBO Int. Corp.
**Mod.:** Korvan 9240 Jatropha Harvester
**Minimum row spacing:** 3.0 m x 1.5 m
**Plant height :** 2.5 - 3.0 m
**Headland:** 6.0 - 8.0 m
**Width:** 3.5 m
**Weight:** 6,000 kg
**Storage:** 500 kg
**Field capacity:** 0.15 – 0.6 ha $h^{-1}$
**Speed:** 1-3 km $h^{-1}$
**Fuel consumption:** 9-12 l $h^{-1}$

# Full mechanized harvesting system: Over-the-Row Harvesters

## BEI Jatropha Wave Harvester



**Company:** BEI inc.
**Mod.:** Jatropha Wave Harvester
**Minimum row spacing:** 3.0 m x 1.5 m
**Plant height :** 2.5 m
**Headland:** 7.5 m
**Note of the constructor:**
the harvester has a CSS (Centipede Scale System) mechanism that is an improved catching system that reduces the damage of the tree.

# Full mechanized harvesting system: Over-the-Row Harvesters

## Jatropha harvester

**Company:** Rakennustempo Oy Ltd
**Mod.:** Joonas harvester
**Minimum row spacing:** 3.5 m x 1.5 m
**Field capacity:** 0. 5 – 0.8 ha $h^{-1}$
**Note of the constructor:**
it can do the job of 100-150 pickers

# Full mechanized harvesting system: Inertia trunk shakers

## Jatropha harvester

Dotan Technologies is an Israeli company that has developed a prototype of shaker harvester provided with a grip to apply to the trunk of the plant to produce a vibration necessary for the selective harvesting of ripe Jatropha fruits

# Full mechanized harvesting system

**Pros:**

- lower labor fatigue compared with other harvesting method;
- high field capacity (ha $h^{-1}$);
- high material capacity (t $ha^{-1}$);
- continuous harvesting;
- reduce labor;
- harvest on demand.

**Cons:**

- high investment requested;
- high machine maintenance level;
- necessity of specific field set up;
- high surface needs to be economically sustainable.
- ground compaction

# Conclusion 1/2

- High mechanization decrease the possibility of selective harvesting; until jatropha plants will not breeded to concentrate ripening in a short period, manual picking will obtain a harvested product with less unripe fruit.

- semi-mechanical harvesting can improve the harvesting performance and improving the workers conditions with very low investment cost;

- Harvesting Jatropha fruits is an intensive labor, time consuming and first cost item of the Jatropha production balance. It can be considered also a source of job for rural communities but only in very low income countries.

# Conclusion 2/2

The choice of the "perfect" Jatropha harvesting method is in relation to multiple parameters, among them:

-Number of ha to be harvested annually
-Harvesting period
-Labor cost
-Harvester purchasing cost
-Maintenance cost
-Diesel cost
-Social conditions
-Ripening period of the crop
-Etc..

For this reason, the choice of the level of mechanization will influence both the economic and social issues, but in the long run mechanized harvesting is a condition for rural areas progress.

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# *Thank you for your attention*

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