UNIVERSITE MOHAMMED 1st
of Oujda

STUDY OF THE POTENTIALITIES OF JATROPHA CURCAS IRRIGATED WITH WASTEWATER (OUJDA; EASTERN MOROCCO)

CHEMICAL COMPOSITION OF THE OIL EXTRACTED FROM JATROPHA CURCAS IRRIGATED WITH WASTE WATER"

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Introduction

In Oujda, city of Eastern Morocco, the reuse of waste water in peri-urban agriculture is a lot of developed and this because of :

- Persistence of drought
- The scarcity of irrigation water
- Agricultural intensification
- The availability of large volumes of waste water mobilized by users.

Introduction

- This practice covers an area of over 1150 hectares (2007), (500 ha, 1995), and interests a great diversity of types of cultures including market gardening.
- The worry to health an environment remains the major constraints in this practice.
- It would be recommended to take the least risks by considering the non- consuming cultures by man and presenting a significant economic interest.

Introduction

We chose a culture of

Jatropha curcas L,

A bio-energetic plant, non- consuming by man, which presents various environmental, social and economic benefits, factors which can participate in rural and even national development.

General knowledge

Jatropha curcas (fruits) irrigated with waste waters in the STEP

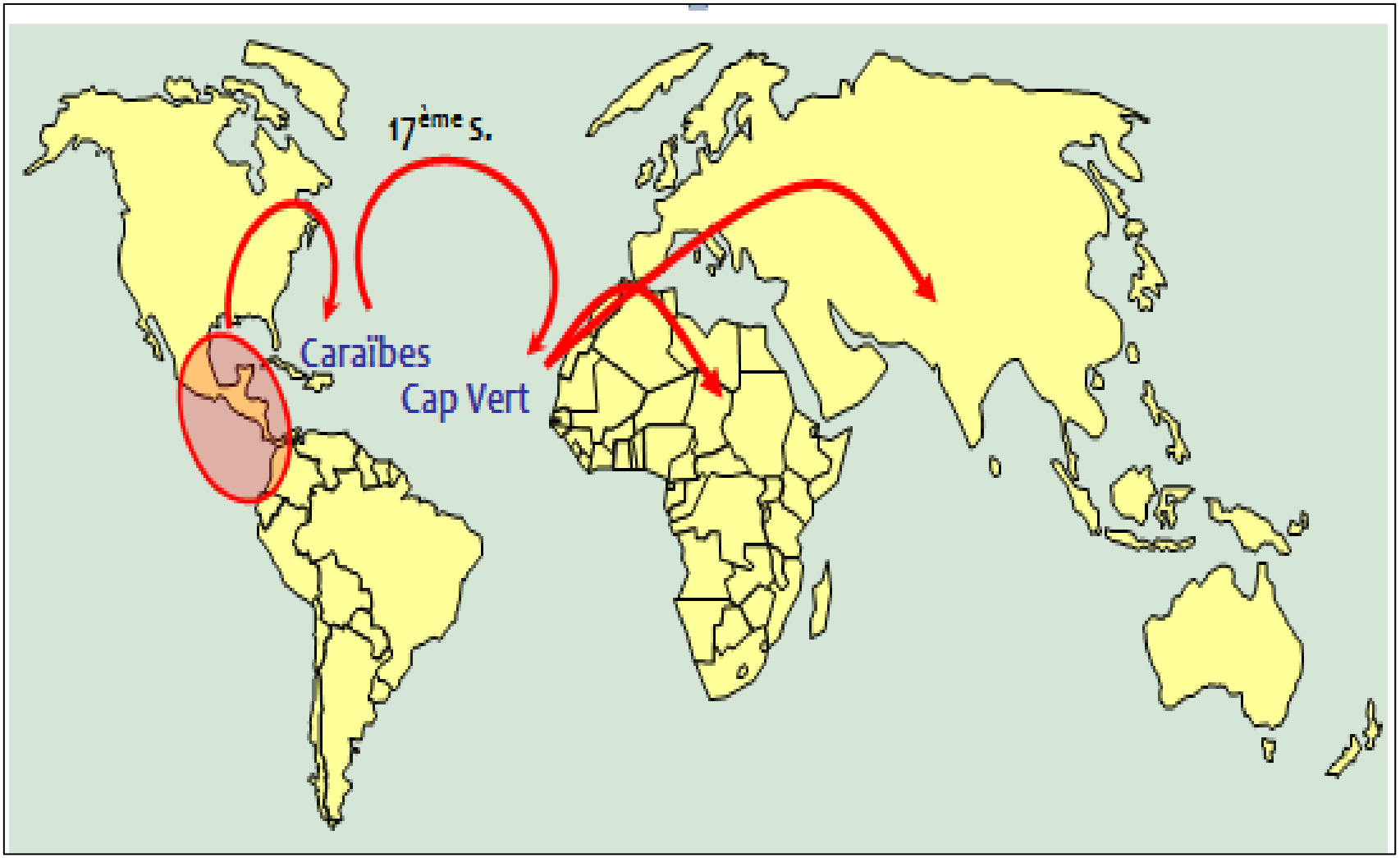
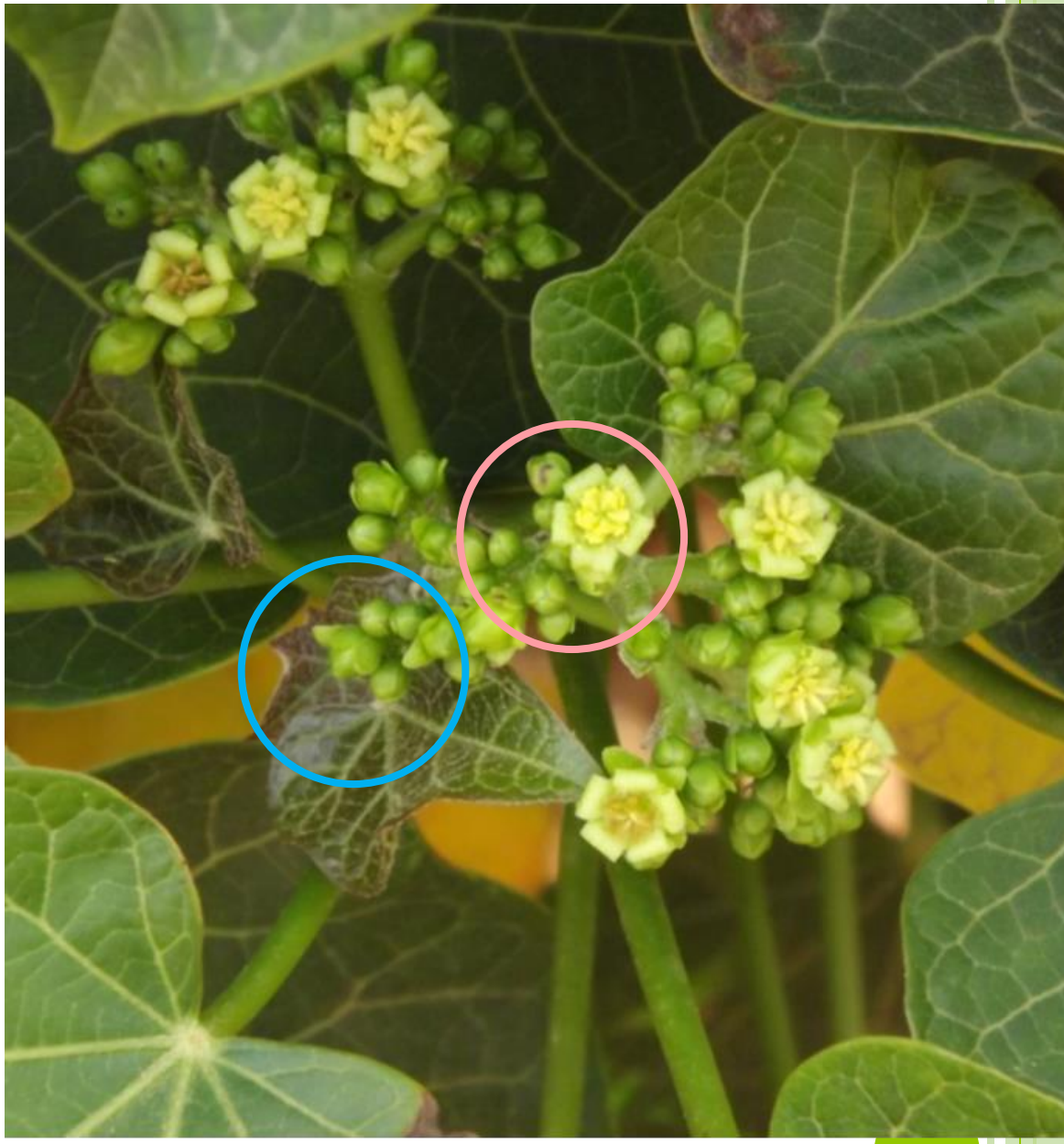


Figure1: Zone of origin and evolution of the storage areas. (Heller, 1996)

- small tree 2 m to 8 m (10m)
- Final Inflorescence
- Flowers male and females carried by the same inflorescence
- Ground: sandy ground filtering draining to avoid the grounds blocked
- female flowers of larger are surrounded by the male flowers. Color greenish with yellowish
- Water requirements: 300 to 600 mm/of a precipitation



Use of Jatropha curcas

- Many uses in traditional medicine
- manufacturing of Candles and soap
- Toothbrushes
- the oil of lamps for lighting
- oil for the kitchen
- biofuel: Fuel in diesel engines after cross esterification. The residues of the extraction can be used to produce biogas after methanisation



The Jatropha Website

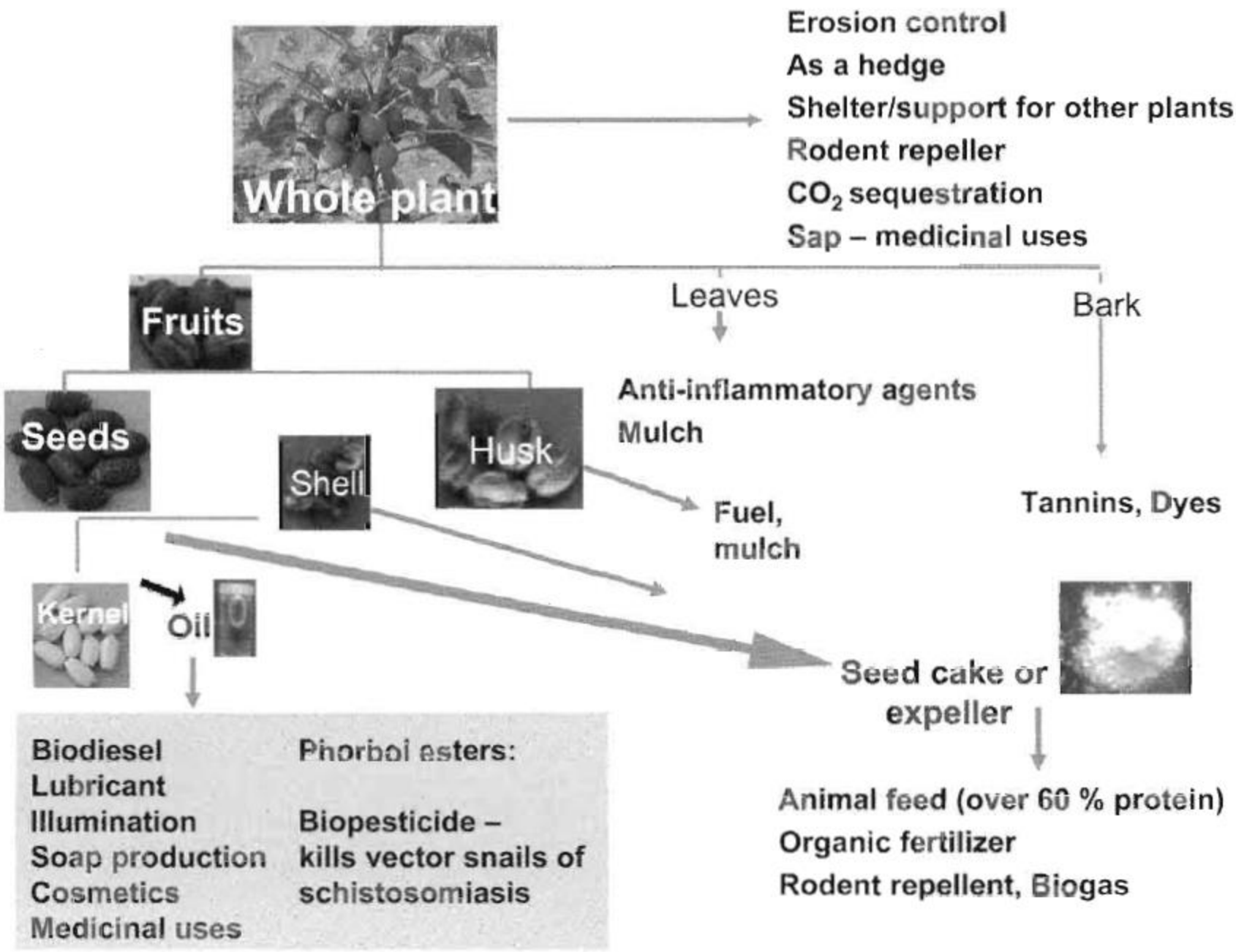


Figure : les divers possibilités d'exploitation de la plante *Jatropha curcas L.* et de ses produits

PLASTIC SPECIES

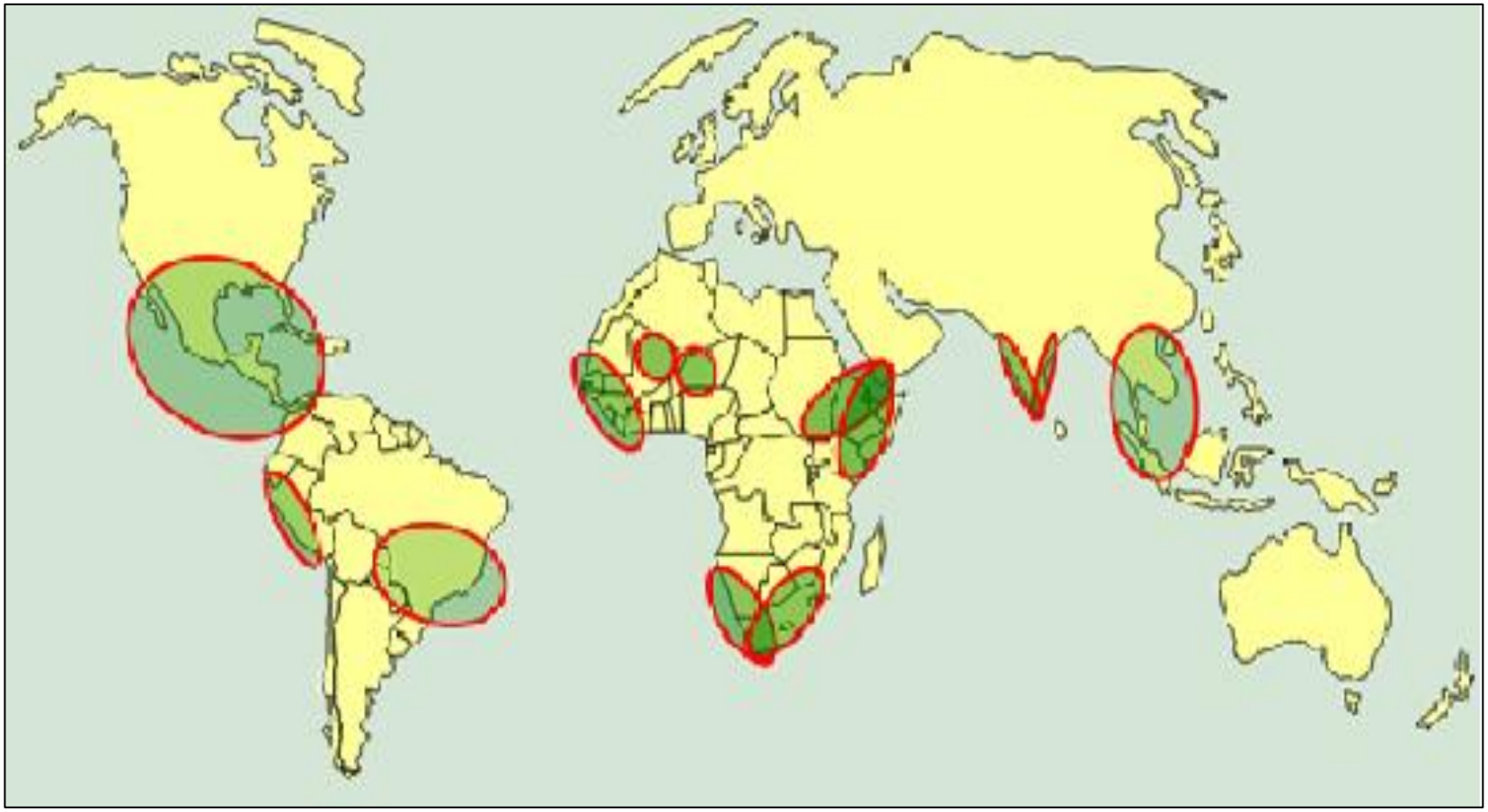


Figure 3: Current surface of distribution of Jatropha. (Heller, 1996)

Tropical zone dries (arid) → Wet tropical forests

In dark green, areas of Africa where the plantation of Jatropha curcas is possible , this Map provides an overview of the climate zones suitable for Jatropha cultivation in Africa.

Source : Energy and Transport Branch Division for Sustainable Development United Nations.

Department of Economic and Social Affair, "**Small-Scale Production and Use of Liquid Biofuels in Sub-Saharan Africa: Perspectives for Sustainable Development**", Commission on Sustainable Development Fifteenth Session, 30 April- 11 May, New York, p 10.

Figure: Potential distribution of Jatropha curcas in Africa and in Morocco

In Morocco, the plantation of the culture of Jatropha is possible

OBJECTIVE OF THE STUDY

- Valorize the wastewater of Oujda city
- Evaluate the impact of wastewater on Jatropha curcas and its growth parameters : its development and its productivity in seed and oil.
- Check its adaptation to arid climate of the city of Oujda especially on winter freeze (Pmm weak, T°C low in winter) and the completion of its biologic cycle.
- follow its biological cycle under the new conditions édapho-climatic of the town of Oujda.
- The success of introduction of Jatropha curcas in area suffering of lack of water and using wastewater.

AGRONOMIC ASPECT OF THE RE-USE OF WASTEWATERS ON JATROPHACURCAS

MATERIALS AND METHODS

STUDY AREA : CLIMATIC CHARACTERISTICS

- The city of Oujda is situated to the northeast of the kingdom, 12 km to the Algerian borders, and 60 km to the Mediterranean coast
- its climate is arid to semi-arid with a continental character (low precipitation)
- Subject to problems of subsidence of water of table and of rivers
- The city has 500 000 inhabitants (2011),
- Produces about 40 000 m^3 of wastewater per day which are routed by the main collectors (C9, C5 et C6) in the river of l'Oued Bounaïm

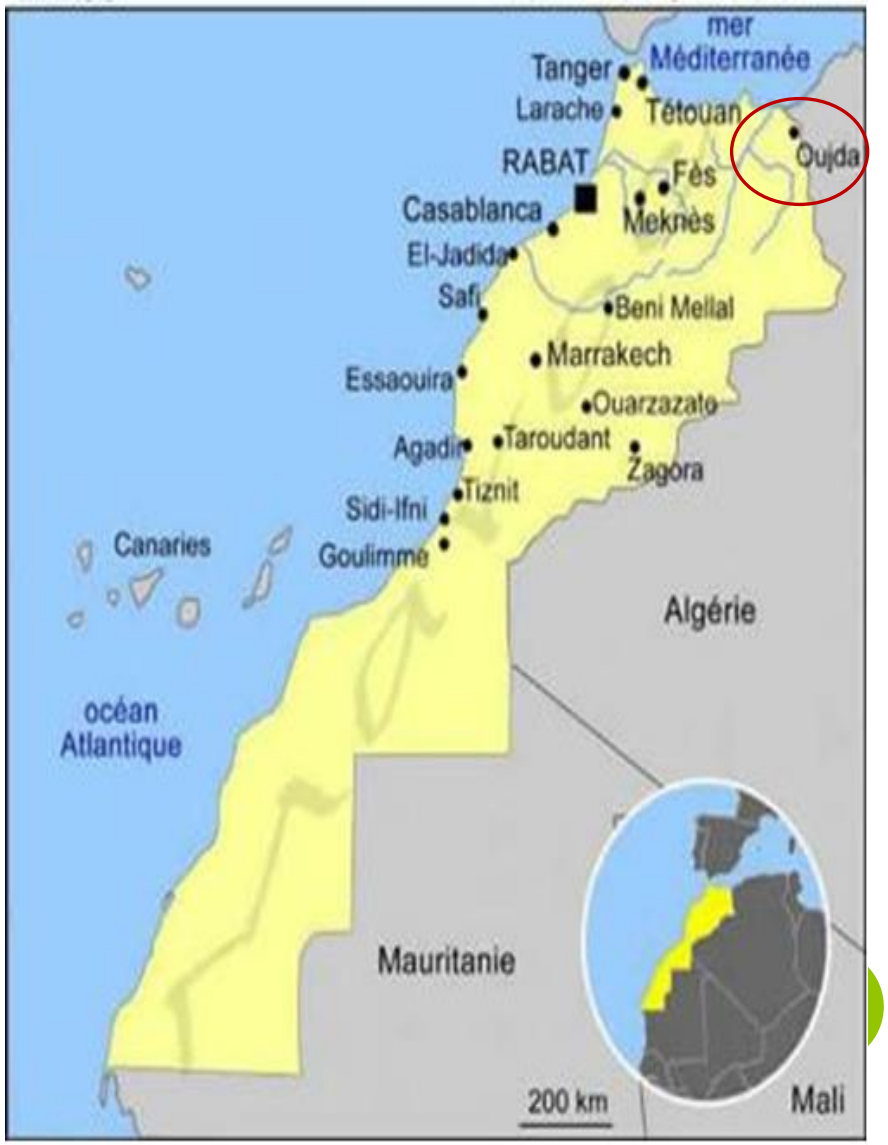


Figure 1 : Localisation de la ville d'Oujda

THE EXPERIMENTAL DEVICE

Photo1 : work of planting cutting of Jatropha (may, 2010)

Photo 2**:** the experimental site after planting Jatropha curcas on three lines

The experimental site : tests of Jatropha curcas have been conducted in the agricultural exploitation N° 18 situated on the left bank of Oued Bounaïm 6 km from the city and 4 km from Algerian border near the STEP of wastewater of Oujda city.

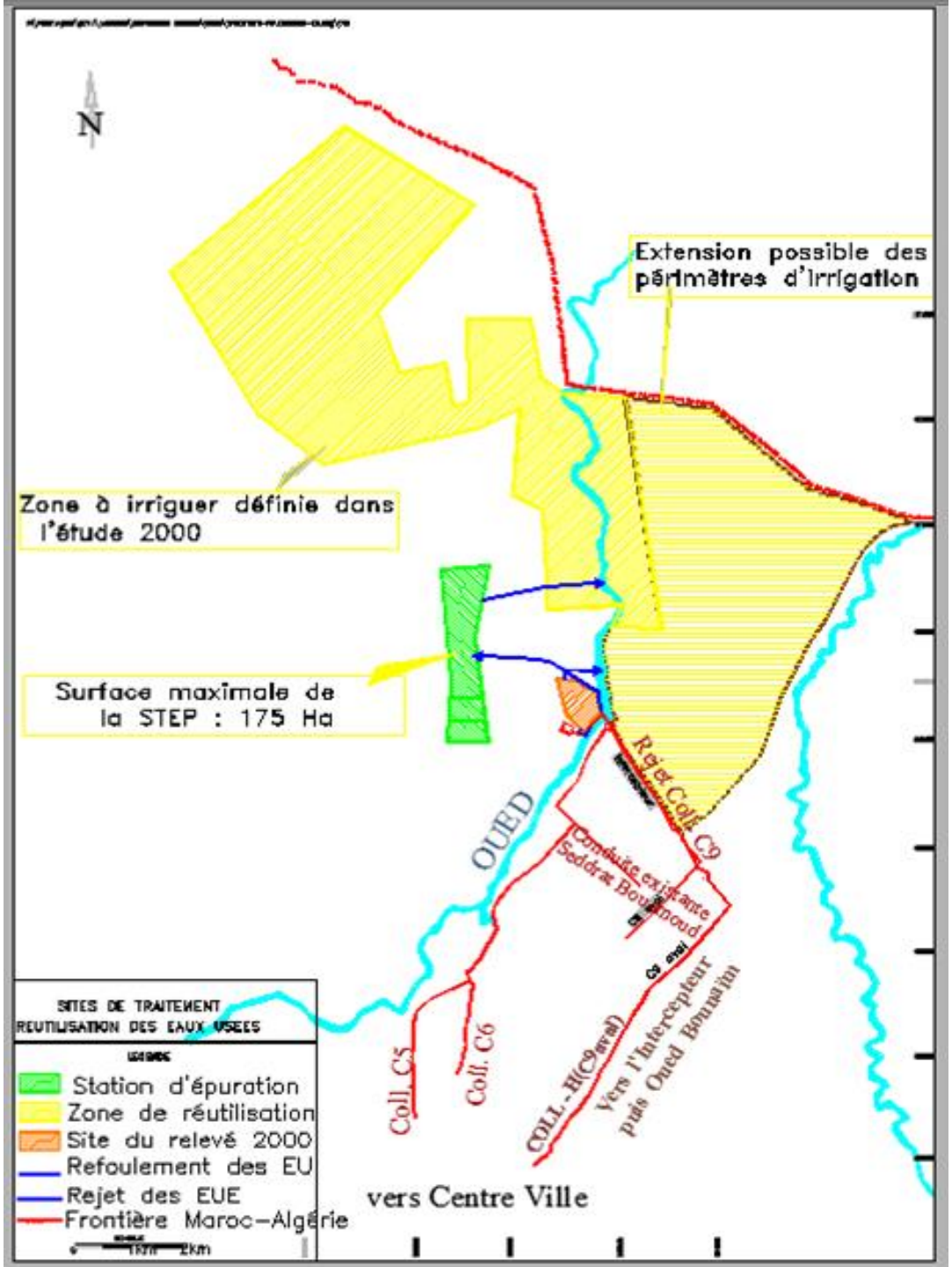
Photos showing the pushing back of sewage (via plastic sheaths) pumped from l'Oued and discharged into a seguia, a source of agricultural irrigation (photo, O. Mokhtari, le Juin, 2010)

THE IRRIGATION OF JATROPHA CURCAS BY TREATED WASTE WATERS

The wastewater treatment plant of Oujda city ' the Aerated lagoon"

1- anaerobic lagoons
2- aerated lagoons
3- maturation lagoons
4- aerated lagoons
5- the drying bed of The sludge

Figure: :Location plan of study site , of the STEP, and the Zone projected of re-use of purified wastewaters in the project of valorization of purified wastewaters of Oujda-city



THE EXPERIMENTAL DEVICE

Photo1: The experimental site : the experimental tests were carried inside the sewage treatment plant. plantation of Jatropha curcas on 5 lines

Results and Discussion

1. Effect of sewage on height growth of Jatropha curcas :

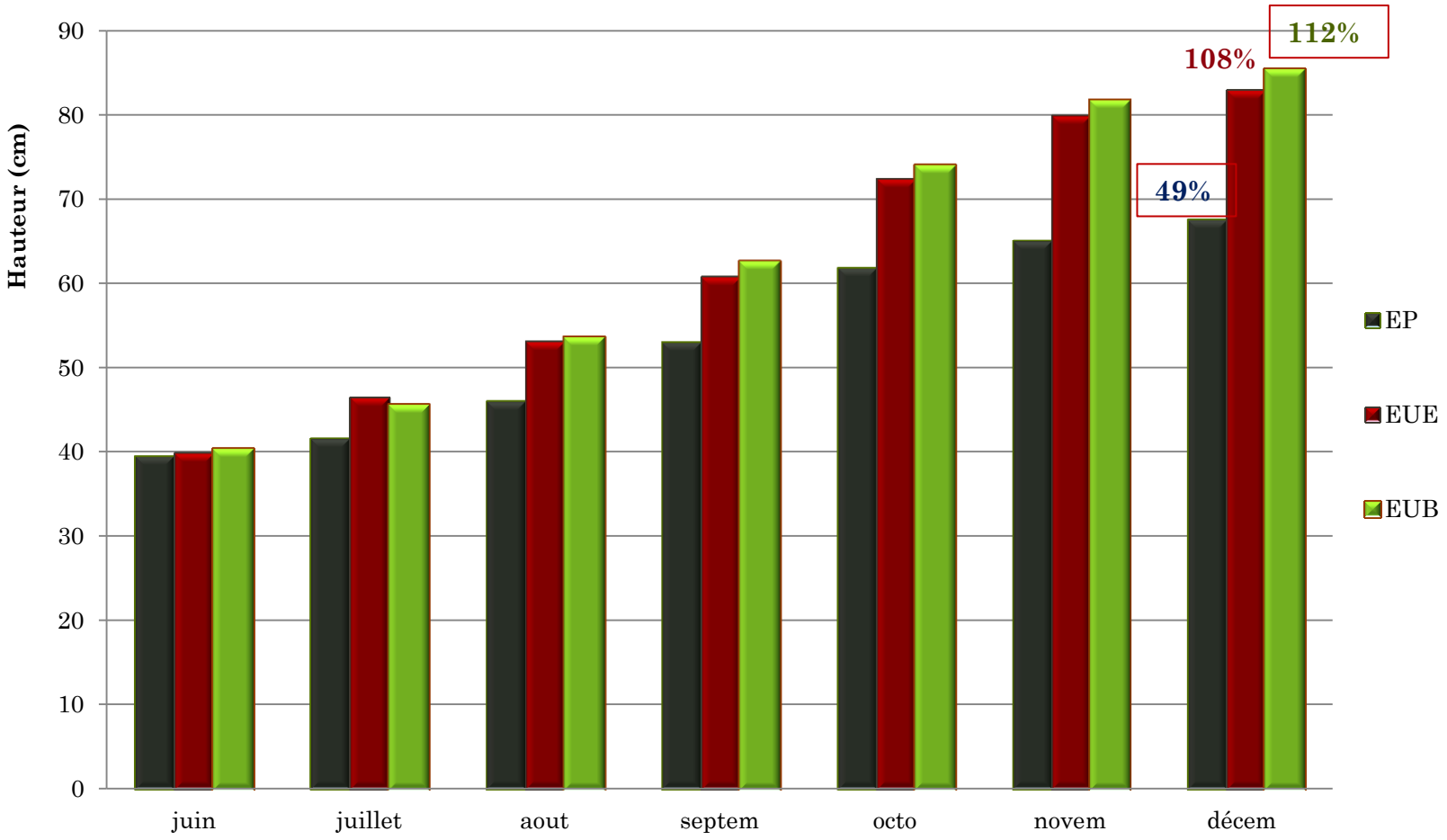
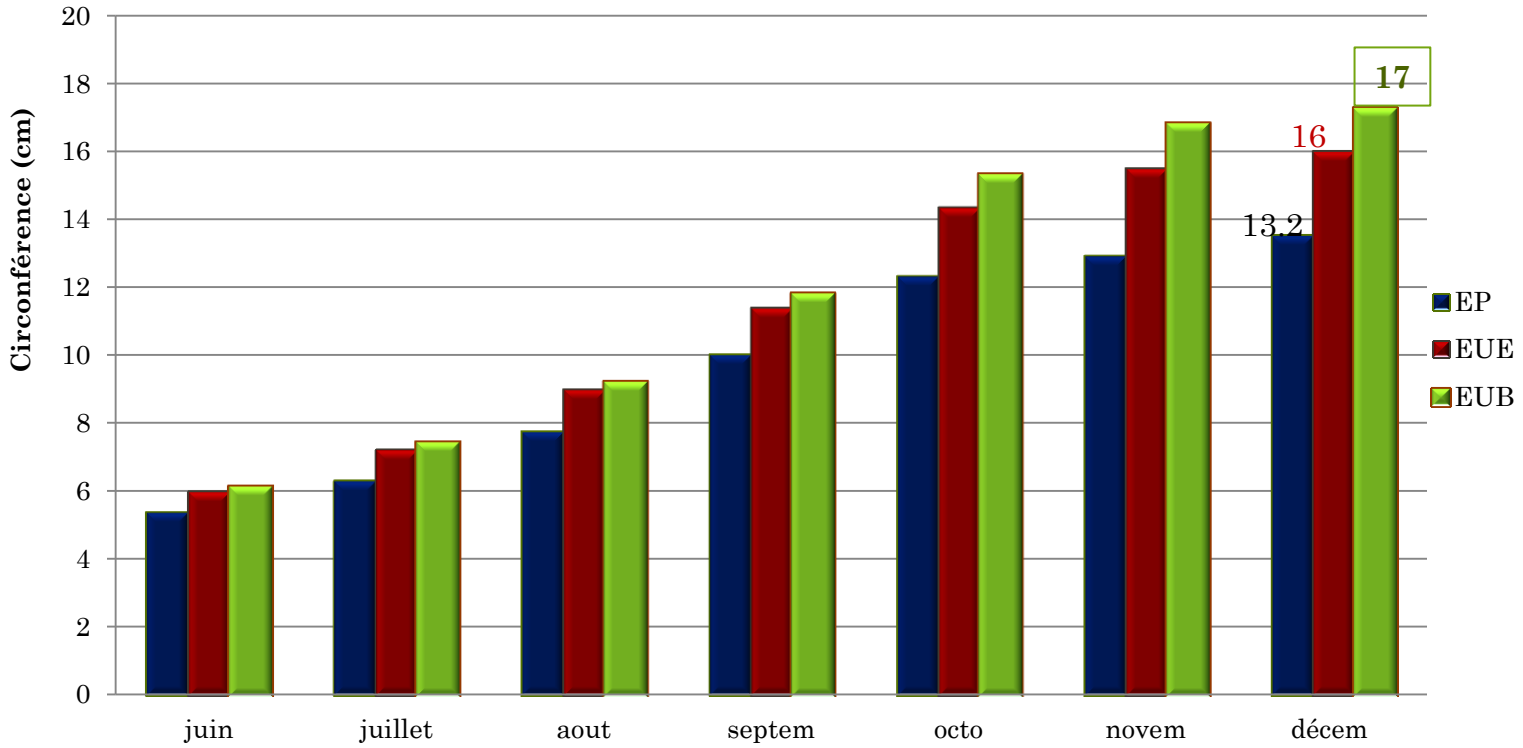


Figure : the height growth of Jatropha curcas according to the type of water of irrigation (EP, EUE,EUB).

- The figure above represents the height growth of Jatropha curcas throughout the test period.
- In general, throughout the test period, the height growth for Jatropha curcas irrigated by wastewater are much more important than that of controls plants. Six months after plantation, the average height is important . an increase of 112 % for raw waste and 108% for sewage purified and only 49% for witnesses.

Photos: Clear improvement of the growth in height at the plants of Jatropha curcas irrigated with raw wastewater . (a) : the level of growth in September, (b) : that reached in November (2012)

2. EFFECT OF WASTEWATER ON THE RADIAL GROWTH OF JATROPHA CURCAS



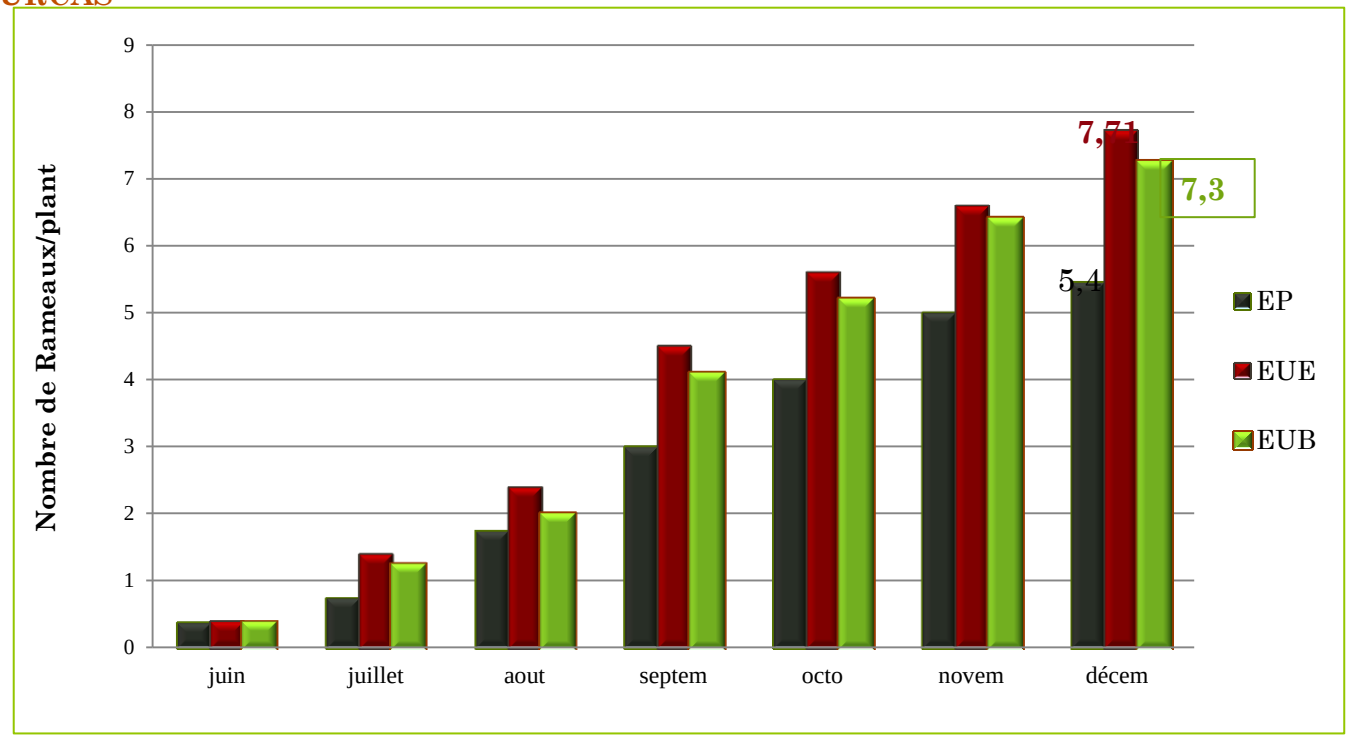
- Figure 3 Effect of wastewater on the diameter of the stem of Jatropha curcas plants

The figure above represent the variation of the diameter of the stem of plants of Jatropha curcas irrigated with wastewater in function of the time.

The increase is significant at the plants irrigated with the raw and the purified wastewater compared to the witnesses

By the end of December, the circumference has averaged 17 cm (RWW) with a maximum of 24 cm, and 16cm (PWW)

3. Effect of wastewater on the ramification and inflorescence of the plants of Jatropha curcas



- **Figure :** Variation of the ramification of the Plants of Jatropha curcas in function to the type of irrigation water
- Throughout the testing period, the rate of increase in lateral of Jatropha plants irrigated with wastewater remained significantly higher than those which are controls.
  The ramification has increased. It goes from an average of 0,4 branches/plant to 7.71 and 7,3 branches/plant (purified and raw wastewater) by the end of December month against only 5.4 on controls plants (with growth rate 41 % more than controls plants)

Photos: Increase in the ramification at the plant of Jatropha irrigated with purified waste water. (a) plant of Jatropha in September, (b) the same plant in the month of December 2012)

Important ramification at the base of Jatropha curcas plants(December 2012)

Photos: Development of the inflorescences, December 2012

- At the end of the trial period:
- The rate of increase in inflorescences at the plants of Jatropha is 44% and 54% respectively for the raw and purified wastewater
- An average of inflorescence of 2,3 inflorescences/plant and 3 inflorescences/plant respectively for raw and purified wastewater.
- It is only of 9 % at the control plant, with an average of 0,5 inflorescences/plant.

- Table of the results of the irrigation of Jatropha curcas with waste waters

Parameters of growth	Height growth		Radial growth		Ramification		Inflorescence
	Height (cm)	the rate, (%)	Circumference (cm)	the rate(%)	Ramification (nbr branches/plant)	the rate(%)	the rate % (the average inflo/plant)
Wastewater raw	85	26 %	17.3	33 %	7.3	**33 %**	44 % (2,3 max 4)
Wastewater purified	83	23 % higher than the control	16	23 % higher than the witnesses	7.71	**41 %** higher than the witnesses	54 % (3 max 5)
water of well Control	67		13		5		9 % (0,5 max 1)

the use of the Wastewater (unpurified and purified) generated a very significant increase in the different parameters of growth

The growth of Jatropha irrigated with wastewaters (unpurified and purified) is similar.

An Increase in the ramification of 41% (purified waste water) and 33% (unpurified wastewater) higher than the controls. and consequently, the number of inflorescence/plant, and an increase in the number of flowers in each inflorescence.

TABLE :A COMPARATIVE TABLE OF JATROPHA NEEDS IN PLANT NUTRIMENT AND THOSE BROUGHT BY WASTEWATER OF OUJDA CITY.

The fertilizing element	Theoretical needs of Jatropha curcas (Reinhardt, 2008) (kg/ha/year)	The contribution of raw wastewater of Oujda city (1000 mm) (kg/ha/year)	The contribution of purified wastewater of Oujda city (1000 mm) (kg/ha/year)
N	81	109	85
P	31	32	25
K	89	127	98

- The increase, compared to drinking water, of different organs of Jatropha curcas is attributed to the rich contribution in plant nutriment of wastewater;
- The wastewater (raw and purified) of Oujda city come to cover and even exceed the needs of Jatropha curcas

Table showing the acceleration of the growth of Jatropha curcas irrigated with wastewater.

Parameters of growth	15 months after plantation (Jean-Daniel et Elsa Pellet,2008)	6 months after plantation (testing results 2010)	6 months after plantation (testing results 2012 at the STEP)	
	Irrigation with fresh water	Irrigation with raw wastewater	Irrigation with raw wastewater	Irrigation with purified
Hight (cm)	150	**126**	86	83
Ramification (branches/plant)	6	**10**	7	7
Circumference (cm)	7,5 à 8,2	**18,2**	17	16

The irrigation with wastewater (raw and purified) :

- Has not only improved the parameters of growth of Jatropha curcas plants (height, the diameters, of stalk, branches) but it also caused its precocious ramification : **Early growth is fast**

- Has contributed in the improvement of productivity by increase in the number of branches/plant and consequently of the number of inflorescences/plant (the inflorescences develop only at the extremity of the branches)

For the results of irrigation with EUB established in 2010, they are much higher compared to the site of the STEP (2012 trials). This difference in performance is due to the high fertility of the soil from the first site

Vegetative development of Jatropha curcas

- **Falling Leaves : In January total fall of the leaves**

	Oujda (use purified wastewater)	Mali
leaf fall	**January (cold season)**	during the dry season (June to August or July to September). According to the aridity of the climate. a Jatropha capacity to resist water stress.
Vary according to the area, is observed in response to extreme climatic conditions: frost or cold during the winter (as in Florida) or dry season		
Formation of new leaves	Mid-April (at witnesses starting from mid-May)	After the dry season (November-December)

Photos: leaves Fall begins with the lower part of the plant (January 2013)

From December, falling leaves is observed. Yellowing, drying and fall. The plant has entered a period of dormancy.

Photos: Left: the newly formed leaves are red. On the right, the leaves turn green and thick (2012)

- The first young leaves are often reddish then become green. At the end of April all the plants begin to form the leaves. Leaf formation in plants irrigated with wastewater precede those of witnesses

Different phase from development of the vegetative cycle of Jatropha curcas	In Oujda (irrigation with wastewater purified)	In different countries
The first inflorescences	at the end of May. And at the end of July, at all seedlings flowering extends until December	In Nicaragua 5 peaks with 2 more important one are in May - June The other are in August-September In Thailand, there are 2 flowering peaks, in November and May. In permanently humid equatorial regions, flowering occurs throughout the year.
	two flowering peaks are observed. **The first flowering peak:** June-July: at the end of July, at all plants (wastewater purified).	
	2nd flowering peak October-November: exactly early October , in number and larger size	
Some inflorescences of 2nd peak can not produce fruit, the development is interrupted by the arrival of the cold winter.		


July


October

Photos : On the left (July), on the right (October), at this stage, the inflorescences are numerous and more developed because the tree has more branches and it is greater

(a)

(b)

(c)

Photo : (a): Plant of Jatropha curcas plant without leaves in May, left the same plant with the formation of sheets (September), right: the same plant more developed with more branches. therefore, more inflorescences (November 2012)

Photo : At the arrival of winter and as a result of cold, the inflorescences have started to blacken and shrivel

At the arrival of winter and as a result of cold, the inflorescences have started to blacken and shrivel .

Photo : Plastic tunnels installed to protect the cultures of Jatropha against the cold and frost (January 2013)

The flowers are pollinated by insects especially honey bees (October 2012).

The first fruits appear in August (green)

(a)

(b)

(c)

photos : (a)The fruits are green, then, they ripen, they become yellow (b). And, (c) drying, the fruits take a dark brown color, then, seeds are ripe.

Table: Summary calendar of the different phases of vegetable development of Jatropha curcas irrigated with wastewater during the year.

Months	January	February	March	April	May	June	July	August	September	October	November	December
falling leaves												
	The vegetable rest											
new leaves												
Inflorescences												
Ripe fruits												
Cuttings		during the vegetable rest										

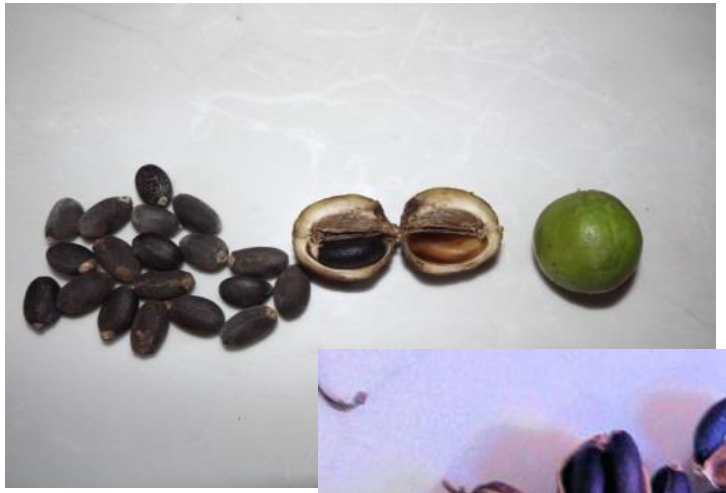


Photo : Green fruit of the size of a walnut (on the left), Ripe fruits and seeds (on the right) ;.

in general, the fruits contain 3 seeds, inside seed is a white kernel.

Table: Description of the fruit of Jatropha curcas in comparison with the bibliographical data

authors		The size (cm)	Weight (g)
Fruits obtained after irrigation with waste waters.	Green fruits	- Length: 2.5 to 3.5 - Width: 1.5 to 3	10,7
	Dry Fruits	- Length: 2,3 to 2,4 - Width: : 2,08 to 1,8	2,3
With fresh water (control)	Green Fruits	- Length : 2,5 to 3,5 - width : 1,5 to 2.8	10,5
	Dry Fruits	- Length : 2,28 to 2,4 - width : 2,1 to 1,8	2,26
NACRO, S. 2011 (Drie Fruits)		- Length : 1,8 to 3 cm - Width : 1,5 to 2,3 cm - Thickness : 1,3 to 2,2 cm	2,16
Münch, 1986. Drie Fruits		- Length : 4 - Width : 3	
Münch, 1986. Drie Fruits		- Length : 1,5 à 3	
François SANOU, 2010. Drie Fruits			2,12 à 2.4

The size and the weight of the fruit and seed of Jatropha irrigated with waste water and Those of the Witnesses remain almost similar, and do not present a difference with those published by various authors referenced.

Table: Weight and size of the seeds of Jatropha curcas, compared with those obtained by different authors

	authors Year	Weight (g)	Dimensions averages (mm)
Cap Vert	José Cuhna Da Silveira, 1934,	0.56 - 0.75	16.7 x 10.9 x 8.1
Portugal	Droit, 1932	0.67	17.7 x11.2 x 8.8
Brésil	Centre Technologique du Minas Garais 1985	0.87	
Mali	Droit, 1932	**0.71**	**17.1 x 11.3 x 8.3**
Results of our tests (2012)	Irrigated with wastewater	**0.56 à 0.75**	**17.3 x 11.29 x 8.44**
	controls	**0.53 à 0.74**	**17.17 x 11.4 x 8.47**

According to the two tables, the irrigation with wastewater does not affect the size and weight of the fruits and seeds of Jatropha, which remain almost identical to those of the witnesses, and those published by various authors referenced .

Chemical Composition of the oil extracted from *Jatropha curcas* irrigated with waste water”

- The objective of this part of study is :
  - To determine the chemical composition in fatty-acid of the oil of Jatropha curcas.
  - To check if the use of waste water can affect the chemical composition

Materials and methods

- Soxhlet extractor (heats balloon and cartridge)
- Balance precision
- Organic solvent n-hexane (250 ml)
- Seeds of Jatropha curcas out of powder (70 G on average)
- the seed kernel of Jatropha curcas
- Rota-steamer

Photo: Right: The chemical extraction of oil seeds (Jatropha curcas)using Soxhlet. Left: ROTAVAPOR. Laboratory of Organic Chemistry, search block Faculty of Oujda (2013)

Materials and methods

Different oil samples (extraction in Soxhlet by solvent):

1.Oil extracted from the seeds of Jatropha curcas irrigated with wastewater

2. Oil extracted from the seeds of Jatropha curcas controls

3. Oil extracted from the seed kernel of Jatropha curcas

The chemical compositions of the oil of Jatropha curcas:

- **Transformation into ester-methyl**

A two-step process compromising : saponification of oil followed (using a basic catalyst (NaOH)), followed by esterification (using a solution of BF3 (trifluorure de bore) in excess in methanol (MeOH)) . the fatty-acid are then transformed into estersmethylic of fatty-acids (EMAG)

- **Quantification by gas chromatography-mass spectrometry (CPG/MS)**

The composition in fatty-acids of oils is determined by analysis of their methyl esters. Their detection and quantification was made by gas chromatography with the mass spectrometry.

RESULTS AND DISCUSSION

Table : content in oil of Jatropha curcas seeds obtained in comparison to the different authors

Site	authors Year	**Oil (% weight kernel)**	**Oil (% weight seed)**
Cap Vert	Cuhna da Silveira 1934	52,5 – 61,7	27.9 – 37,3
Madagascar	Droit 1932	55	37,4
Côte d'Ivoire	Amman	49,2-59,4	32,1 – 37,8
Congo	Adriaens	51,2-58,2	35.1 – 37,8
Sénégal	Station de Bambey	48,2-50,6	29,9 – 32,6
Sao Tomé	Ferrao 1982	46,7	23,7
Inde			28 - 38,3
Nicaragua	Projet Biomasa 2003	41,1	29,7
Brésil	CETEC 1985	60,8	38,1
Mali	Rathbauer. J, et al. 2012		**21 % à 35 %**
Results of our tests (2013)	Irrigated with wastewater	**46 à 47 %**	**28 à 32 %**
	controls	**42 %**	**23 à 25 %**

the improvement of oil content is about 30% :

- Jatropha seeds irrigated with wastewater : oil content is 29 to 32% (% v/w)(similar to that produced in the majority of countries in Africa and Mali).
- The Seeds of witnesses contain 23-25% oil
- The high oil content was observed at the kernels: 46-47%, while 42% of controls

Table : Fatty Acids in *J. curcas* seed oil from each sampling (%).

Fatty acids	Oil 1 (by raw wastewater)	Oil 2 (seed control)	Oil 3 (kernel of seeds)
Palmitic acids	8,54 %	11,86 %	13,68 %
Stearic acides	21,17 %	20, 08 %	22,06 %
linoleic acids	25 %	32,27 %	43,80 %
Oleic acids	22,49 %	15,01 %	20, 46 %

Among different samples we noted predominance of linoleic acid :

- Indeed, the linoleic acid (polyunsaturated) ranged from (25 % à 44 %).

The oil of Jatropha obtained is unsaturated, linoleic type (majority fatty-acid).

For the oil of the seeds (waste waters), the proportion of the unsaturated and saturated fatty-acids is respectively of (50.47% and 32.24%), That of the witness is of (47,3% and 32%)

The irrigation with waste waters did not cause a great modification in the nature of oil and its composition in fatty-acid major compared to that of the witnesses. For the two types of sample (irrigated with waste waters and witness), oil is unsaturated of linoleic type.

Table: Chemical Properties of the Jatropha curcas oil

	Colza	Palme	Jatropha curcas							
Origine			Brésil	Inde	Thaïlande	Togo	Zaïre	Egypte (irrigation avec EU)	Mali	Maroc, Oujda
Auteurs	Vaitilingom	Vaitilingom	Tapanes	Nasirullah	Chedchant	Kpoviessi	Gaydou	G .EL Diwani	Liennard	La moyenne des résultats de notre étude (2013)
	2007	2007	2007	1987	2004	2004	1982	2009	1994	
Saturés										
Palmitique C16: 0 (%)	5	42-48	16 max	12-17	14,7	15	28,4	18.22	15,2	11.36
Stéarique C18:0 (%)	1 à 2	05-6	6- 7	5-6	6,9	6	3,9	5.14	6,6	21,10
Mono-insaturés										
Oléique C18:1 (%)	58	36-45	42-43,5	37-63	42,6	44	35,7	28.46	44	**20**
Di-insaturés										
Linoléique C18:2 (%)	22	6 - 10	33-34,4	19-40	35,2	35	30,1	48.18	32,6	**34**

- the oil extracted seeds of Jatropha curcas is generally unsaturated of oleic type. The seeds contain around 20% saturated fatty acids and 80% unsaturated fatty acids, and they yield 25%–40% oil by weight. (Domergue, Mr. et al., 20008, Nzikou. J.M. et al., 2009.Kpoviessi. D, et al. 2004, Nguyen VanCuong, 2010)

- The oil that was obtained shows a predominance of linoleic acid instead of oleic acid, which is only 20%. The oleic acid values were low with those generally obtained in the majority of countries in Africa, being significantly higher than oils of this study

- The similar result to that obtained in Egypt where Jatropha irrigated with waste water gave an oil unsaturate with the prevalence of the linoleic acid

- The oil is largely made up of linoleic acids in our results with a rate of 34%..

- For the saturated fatty acids : The result showed a higher content of saturated fatty acids in the oils (32.5 %)
    1. The palmitic acid shows the same rate (11,4%) that obtained in the majority of the countries.
    2. A very high rate in stearic acid of 21.10%, generally did not exceed a rate of 7%, therefore the rate of saturation of oil increased.

Conclusion

- *From the results obtained, it is found that the plantation of Jatropha is possible in the semi-arid climate of Oujda which may result in a growth of the number of branches/plant, number of inflorescences/plant and the number of flowers/inflorescences, present positive values.*

- *Our results also report that the plant of Jatropha curcas has positively reacted to the irrigation with waste water.*

- *The growth parameters of Jatropha are best for cultivation irrigated with waste water than those irrigated with natural water.*

- *The contribution of the rich nutrient of wastewater in improving the productivity of Jatropha by the increase in the ramification and the fast and early formation of the inflorescences.*

- Under the new pedoclimatic conditions of the town of Oujda, the vegetative development cycle of Jatropha curcas, its duration, the production, seeds, their maturity and their content of oil, seem very dependent of the conditions climatic (moisture and Temperature), edaphic and of fluid intake rich in fertilizing elements.

- The Wastewaters improvement of yield of Jatropha curcas by:
  1. Increase in the ramification and the inflorescence
  2. Acceleration of the vegetable development process (Acts over the duration of the cycle which is shortened)
  3. Improvement of the oil content of Jatropha seeds of approximately (30%)

- the growth and the yield of Jatropha curcas (seeds and oil) are significantly improved by a rich fluid intake in nutrients provided by the wastewater.

- Jatropha can develop on an excessively saline ground (7 mmohs/cm)

Conclusion

- The present part of study show the influence of the new édapho-climatic conditions of the town of Oujda on the quality of the oil of Jatropha curcas and its composition in fatty-acid.

- In general, oil of Jatropha curcas is unsaturated linoleic type, and contains mainly fatty acids linoleic acid (34%), oleic (20%), stearic (21.01%) and palmitic (11.36%).

Conclusion

In the climatic context like ours, characterized by recurrent draught and a permanent hydric deficit, the use of natural water for the growth of Jatropha curcas would not be reasonable.

The use of waste water will therefore represent an opportunity and a solution that would help both :

- *To exploit the resources which this plant offers*
- *to valorise the waste water as a source of irrigation and fertilization*
- *To eliminate these waters in a safe manner.*

Thank

you

For

your

attention