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Effect of drying temperature and conservation conditions on seed viability and seedling vigour in oleaginous gourd (*Lagenaria siceraria*)

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ABSTRACT
Objectives: Production of high agronomic quality seeds is a prerequisite for improving the productivity of oleaginous *Lagenaria siceraria*. This study aimed at testing the effect of drying temperature and storage conditions on seed germination and seedling vigour of both oilseed cultivars "round-fruited" (RFC) and "blocky-fruited (BFC) of this species.
Methodology and Results: Seeds of both cultivars (RFC and BFC) were dried at three different temperatures (16, 30 and 40° C), then stored under 6 conditions [-18°C, 4°C, control at room temperature (RT: 24-30°C):, ash + RT, smoking (50 to 60 ° C) once / week + RT and smoking (50 to 60°C) twice / week + RT)] for four durations (0, 2 , 4 and 6 months). Seeds from these 18 treatments were sown for viability and vigour tests. The results showed that drying temperature significantly reduced the seeds moisture content (from 8.93 to 7.14 %) while increasing seedlings vigour. Moreover, the relatively high initial viability (about 85%), confirmed the orthodox nature of *L. siceraria* and indicates that drying temperature can fluctuate between 16°C and 40° C without damage to the seed embryo. Dried seeds viability and seedling vigour globally decreased slightly during the 6 months of storage. However this decline level was low at low storage temperature (-18°C and 4°C), mean at RT especially in presence of ash and fast with smoking (50 to 60°C).
Conclusions and application of findings: the seeds of both cultivars (RFC and BFC) can be dried at RT that is harmless for their embryo. In order to slow down seed viability loss and seedlings vigour decline over time, these seeds must be stored at low temperature (-18°C and 4°C) or at least in the presence of ash at RT in rural areas but never above the kitchen chimneys that produces too hot smoke (50 to 60° C).
Key words: *Lagenaria siceraria*, drying temperature, conservation, viability and vigour

INTRODUCTION
The importance of any genetic resource could be measured through its uses and fulfilment of population's needs (Shackleton, 2002). *Lagenaria siceraria* is one of the most important plant species for human thank to its multiple uses favoured by the very great morphological diversity of its fruits (Morimoto *et al*., 2005). This large group of plants consists of calabashes and bottle-gourds used as containers or music instruments since antiquity to present while oleaginous ones produce oilseeds consumed as soup in most tropical Africa and Asia areas (Zoro Bi *et al*., 2003). Due to its yield related

to big fruits and large seeds (Morimoto *et al*., 2005). *L. siceraria* shows the best agronomic potentialities among the oleaginous cucurbits. The nutritional richness of its seeds and its extraordinary adaptation to various cropping systems characterised by a minimum of inputs make this plant an excellent agricultural model (Zoro Bi *et al*., 2006). Moreover, the trade of its seeds represents an important income source for farmers, mainly women, in West and Central Africa (Zoro Bi *et al*., 2003; Achigan *et al*., 2006; Zoro Bi *et al*., 2006). In spite of the important roles played by this oleaginous cucurbits group, studies on their technical itinerary and seed production are rare (Chweya and Ezaguirre, 1999; IPGRI, 2002). This is why the poor seed yield and low germination rate widely reported in these species. It discourages the peasants in practice of their culture, which confirms their negligence (Achigan *et al*., 2006). Nerson and Paris (1988) previously showed in cucurbits that production of high-quality seed depends on fruit age at harvest and their extraction procedure. In previous study on *Lagenaria siceraria*, it already reported that seeds reach optimal maturity when fruits are harvested at 50 days after pollination, pre-stored for 60 days after harvest and fermented up to 10 days (Yao *et al*., 2012). Once fermented, seeds must be extracted, washed, dried then conserved for future use. According to Ullmann *et al.* (2010), drying is the most used process to ensure quality and stability in the post-harvest treatment of plant products such as seeds. Because, it decreases water amount in seeds then reduces the biological activity, the chemical and physical changes which occur during storage. Seed drying mainly depends on room temperature and relative humidity for a given seed moisture content (Hong & Ellis, 1996). Furthermore, dried seeds storage is a vital and very important process for agriculture, as it not only protects them for the next season for the plantation purpose but also maintains their quality for the commercial purposes (Sing *et al*., 2017). Efficient storage requires good initial quality, and good drying conditions that avoid loss of physiological quality such as temperatures below 20°C and relative humidity below 60% (França-Neto *et al*., 2010, Surki *et al*., 2012). For seeds of *L. siceraria* oleaginous, studies on their drying temperature and good storage conditions are rare or scant. In our knowledge rural famers used to sundry seeds and conserve them under ambient conditions such as smoking above cookers. This traditional conservation method should be tested. Therefore this study aimed at testing the effect of drying temperature and conservation conditions on seed germination and seedling vigour in oleaginous *L. sicerararia.*

MATERIAL AND METHODS

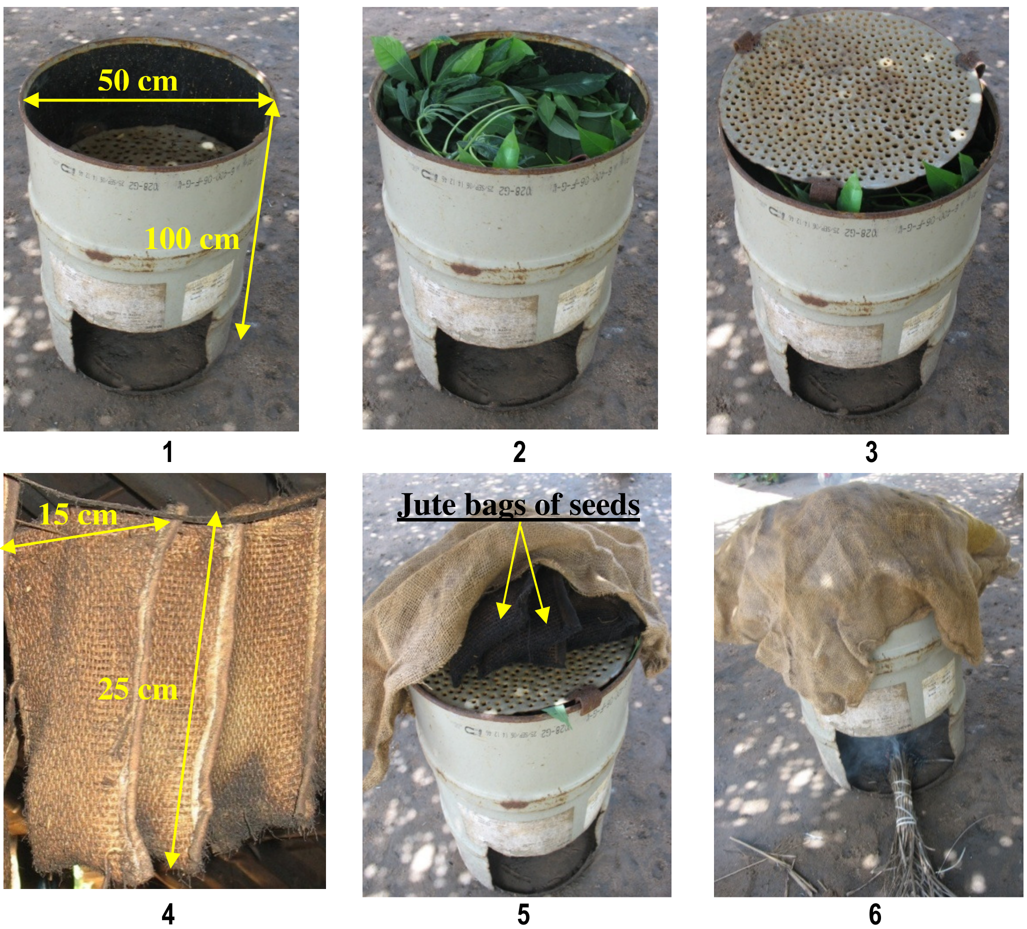
Plant material: Two accessions from oil seeded of *L. siceraria* cultivars; recognizable by the fruit shape (blocky or round) were used. Seeds from the round fruit cultivar (BFC) are characterized by the presence of a cap on the distal side whereas those from the blocky fruit cultivar (RFC) lack this cap (**Figure 1**). These seeds were obtained from the cucurbits germplasm of Nangui Abrogoua University (Abidjan, Côte d'Ivoire) where they are recorded under alphanumerical codes NI304 for RFC and NI195 for BFC. Fruits of both cultivars were produced during the great (April to July: experiment 1) and the small (September to December: experiment 2) rainy seasons in 2008 at the experimental station of this University. In each experiment, the harvested fruits were stored at the farm for 60 days after harvest before fermentation tests started.

1-Blocky fruit **2**-Seeds of blocky fruit **3**-Round fruit **4**-Seeds of round fruit

Figure 1. Fruits and seeds of both oleaginous cultivars (blocky and round) of *Lagenaria siceraria*

Seed drying at different temperatures: After fruits fermentation in plastic bag for 10 days (Yao *et al*., 2013), seeds were manually extracted, washed with tap water and immediately carried to laboratory for different tests. For each cultivar (RFC and BFC), three lots were constituted for drying at 16 ± 2 °C under air conditioner (relative humidity RH= 44 to 50 %), at 30°C (RH = 30 to 35 %) in the small oven (*Binder*) and at 40°C (RH= 28 à 30 %) in the big oven (*Ecocell*) until constant weight. Seed moisture content was determined after 17 hours of oven drying at 103 ± 5°C according to ISTA rules (ISTA, 1996).

Seed conservation under different conditions: Seeds of each cultivar (RFC and BFC) from the 3 drying temperatures (16, 30 and 40 ° C) were packed in glass bottles, rubber cans and small sisal bags for conservation. Six storage conditions were tested: -18° C in freezer, 4° C in refrigerator, wood ash at room temperature (RT: 24 to 30° C), smoking (50 to 60° C) once a week + RT, smoking (50 to 60 ° C) 2 times / week + RT and control at RT. Seeds smoking was carried out using a device consisting of a small barrel pierced at the base to receive the smoke fuel (dry oil palm leaves). Fresh cassava leaves, inside the device, allowed the smoke to cool before it reached the seed bags on the perforated top lid (**Figure 2**).



1- smoking barrel (empty and open), **2-** barrel filled with fresh cassava leaves, **3-** barrel covered with its perforated cover, **4-** jute bags of seeds for smoking, **5-** jute bags of seeds placed on the cover of the barrel and covered with a large bag and **6-** bags of seeds being smoked.

Figure 2. Main stages of *Lagenaria siceraria* seeds 'smoking**.**

Seeds germination and seedlings vigour tests

✓ **Initial viability and vigour tests:** Before storage, the initial viability as well as vigour of each seeds lot dried at 16, 30 and 40° C was tested through the germination test. The sowing device, at the experimental farm of Nangui Abrogoua University, consisted of two completely randomized blocks with five replications each one. Blocks were 3 m spaced and the plots, 0.5 m within them. Constituting a repetition, each plot of 2 m × 1.20 m and, comprised the 6 treatments (3 drying temperatures × 2 cultivars) randomly distributed. Each treatment consisted of 20 seeds sown at 3 cm depth and a spacing of 7 × 7 cm. Sowings were done on raised beds (30 cm height mounds). Seed viability was evaluated using the seed germination percentage (GeP) and germination speed index (GSI). Sowing seeds were considered as germinated when the cotyledons appeared above the ground level. The sown seeds were surveyed daily for 14 days (ISTA, 1996). The germination speed index (GSI) was calculated using the formula suggested by Maguire (1962) as follow:

$$GSI = \frac{G_1}{N_1} + \frac{G_2}{N_2} + \cdots + \frac{G_n}{N_n}$$

where: G1, G2, and Gn represent the numbers of germinated seeds on the first count, the second count, and the last count; N1, N2, and Nn are the numbers of days elapsed of the first, second, and last count. The seed vigour was examined through the seedling emergence percentage (EmP), emergence speed index (ESI), shoot length (SSL), and dry weight (DWS). A seedling was considered as emerged when its two cotyledonary leafs were completely opened (Koffi *et al*., 2009). The seedling emergence speed index (ESI) was also calculated on the basis of the procedure used by Maguire (1962) according to the following equation:

$$ESI = \frac{E_1}{N_1} + \frac{E_2}{N_2} + \cdots + \frac{E_n}{N_n}$$, were:

E1, E2, and En represent the numbers of emerged seedlings on the first count, the second count, and the last count; N1, N2, and Nn are the numbers of days elapsed of the first, second, and last count

✓ **Periodic viability and vigour tests:** During each conservation experience (experiment 1: January to June 2009 and experiment 2: June to November 2009), seeds of each of the 18 treatments (three drying temperatures × six storage conditions) per cultivar BFC and RFC were selected at 2, 4 and 6 months for germination and vigour tests. Seed viability was assessed through three parameters (seed moisture content, germination percentage and speed index) and seedling vigour *via* four parameters: emergence percentage and speed index, shoot length and dry weight of the seedling (Egli & Tekrony, 1995, Al-Maskri *et al*., 2004; Larsen & Bibby, 2004; Ghassemi-golezani & Esmaeilpour, 2008).

Statistical analysis: All the collected data was statistically analysed. Percentage data were arcsin transformed before analysis (Little, 1985) but untransformed data were used to calculate means to present the results. Multivariate analysis (MANOVA) using the five- factors model (experiment, cultivar, drying temperature, storage temperature and conservation conditions) was used to test individually these factors and their different interactions. Factors and interactions of significant agronomic importance were studied through analysis of variance (ANOVA) for analysis first before and then during conservation. When the null hypothesis was rejected for each parameter, multiple comparisons using the Least Significant Difference (LSD) test were carried out to determine to identify the factors responsible of this difference. All these tests were performed with SAS software (SAS, 2004).

RESULTS AND DISCUSSION

Global effect of studied factors (MANOVA): Multivariate analysis (MANOVA) revealed that all the 5 studied factors (cultivar, experiment time, drying temperature, storage temperature and storage time) significantly (P <0.001) affected seed viability and produced seedlings vigour. As the viability and vigour performances obtained in each cultivar (RFC and BFC) were not influenced by the experimental time, the results of both experiments were combined and only the means are presented for each. In addition, since only drying and storage temperatures have an agronomic importance during seed conservation, these two factors have therefore undergone a variance analysis (ANOVA) with two classification criteria.

Effect of seed drying temperature ; Increasing the drying temperature (16 to 40°C) significantly reduced the seeds moisture content from 8.17 ± 0.05 to 7.14 ± 0.06% in BFC and from 8.93 ± 0.07 to 7.81 ± 0.03% in RFC while the initial viability (GnPe, GSI) did not change (**Table 1**). For cons, the values of seedlings vigour both parameters (SSL and SDW) increased with seed drying temperature to reach their optimum at 30° C. The seed drying temperature reduces their moisture content while it improves the vigour of produced seedlings with an optimum at 30° C.

Table 1. Effect of drying temperature on seeds viability and seedling vigour of both cultivars of *Lagenaria siceraria* oilseed.

Cultivar	Parameters[1]	Seed Drying Temperatures			Statistics[2]	
		16°C	30°C	40°C	*F*	*P*
RFC	SMC (%)	8.17 ± 0.05[a]	7.63 ± 0.06[b]	7.14 ± 0.06[c]	67.01	<0.001
	SSL (mm)	75.49 ± 13.09[b]	79.03±23.20[a]	74.49±13.75[b]	25.35	<0.001
	SDW (g)	0.27 ± 0.09[b]	0.30 ± 0.09[a]	0.25 ± 0.07[b]	16.76	<0.001
	GnP (%)	84.95 ± 13.82	82.73 ±17.28	84.76 ± 15.69	0.65	0.521
	EmP (%)	75.94 ± 21.73	78.34 ±21.13	78.91 ± 20.38	0.59	0.553
	GSI (Sd/d)	3.18 ± 0.75	3.28 ± 0.85	3.12 ± 0.86	1.07	0.344
	ESI (Sdl/d)	1.83 ± 0.50[b]	2.10 ± 0.60[a]	2.01 ± 0.60[a]	5.76	0.003
BFC	SMC (%)	8.93 ± 0.07[a]	8.24 ±0.07[b]	7.81 ± 0.03[c]	70.8	<0.001
	SSL (mm)	78.71 ± 14.90[b]	80.30 ±15.13[a]	77.25 ± 11.63[c]	15.21	<0.001
	SDW (g)	0.32 ± 0.09[b]	0.34 ± 0.27[a]	0.32 ± 0.10[b]	4.04	0.017
	GnP (%)	78.49 ± 21.01	77.54 ± 23.32	76.93 ± 18.67	0.15	0.863
	EmP (%)	66.50 ± 26.66[b]	73.3 ±24.577[a]	71.93 ± 22.53[ab]	2.30	0.010
	GSI (Sd/d)	3.06 ± 0.80	3.09 ± 0.85	3.01 ± 0.82	0.24	0.791
	ESI (Sdl/d)	1.60 ± 0.58	1.79 ± 0.59	1.68 ± 0.54	2.98	0.052

[1] SMC : seed moisture content ;SSL : seedling shoot length, SDW : Seedlings dry weight of GnP : germination percentage, GSI : Germination speed index, EmP : emergence percentage, ESI : Emergence speed index, Sd/d : seeds/day et Sdl/d : seedlings/day
[2] In each row, the values with the same superscript letter are not significantly different from each other

Effect of seed conservation conditions: Apart from the seedlings dry weight in BFC, seed storage temperature significantly affected all the other viability and seedling vigour parameters (*P* <0.001) in each cultivar (**Table 2**). Compared to the control or room temperature at 24 -30° C (71.29 ± 23.19%), low storage temperatures (-18 ° C and 4 ° C) maintained the highest germination speed index for RFC (respectively 91.57 ± 6 , 35% and 83.51 ± 14.97) and GS (85.90 ± 10.39% and 84.61 ± 10.61%). For cons, the relatively high temperatures (50 to 60 °C) with smoking especially twice a week favoured seed viability decrease to 70.71 ± 25.86% and 59.64 ± 31.87% respectively in RFC and BFC. In addition even at room temperature (24 to 30 ° C), the presence of ash maintained the germination speed relatively higher in RFC (85.18 ± 12.12% *versus* 81.75 ± 12.44 %) and BFC (83, 48 ± 13.33% versus 80.12 ± 11.87%) compared to the control. Similarly seed germination speed index (GSI), the seedling emergence percentage (EmP) and speed (ESI), the seedling shoot length (SSL) and dry weight (SDW) were maintained at low storage temperatures (-18 ° C and 4 ° C) but reduced by smoking once and twice / week at relatively high temperatures (smoking at 50 - 60 ° C). In oleaginous *Lagenaria siceraria*, decreasing the storage temperature maintained seed viability and seedling vigour. At room temperature, seeds longevity and seedlings vigour are improved by the ash while they are damaged by smoking mainly twice / week.

Table 2. Seed viability and seedlings vigour parameters of both oleaginous cultivars of *Lagenaria siceraria* following conservation conditions.

Cultivar	Parameters[1]	Seed Conservation Conditions						Statistique[2]	
		-18°C	4°C	Ash at RT (24 to 30°C)	Smoking (at 50 -60 °C) + conservation at RT (24 à 30°C)		Control at RT (24 à 30°C)	*F*	*P*
					Once / week	Twice / week			
RFC	SSL (mm)	82.15±13.70^{a}	79.59 ±26.12^{ab}	77.52 ±13.35^{bc}	70.64 ± 15.00^{d}	67.81 ± 16.08^{e}	73.00 ±14.35^{cd}	3.31	0.005
	SDW (g)	0.30 ± 0.07^{a}	0.29 ± 0.09^{a}	0.30 ± 0.07^{a}	0.28 ± 0.10^{b}	0.29 ± 0.10^{ab}	0.28 ± 0.08^{b}	4.93	<0.001
	GnP (%)	91.57 ± 6.35^{a}	89.62 ± 7.57^{ab}	85.18 ±12.12^{bc}	78.57 ± 17.71^{d}	70.71 ± 25.86^{e}	81.75 ± 12.44^{b}	13.00	<0.001
	EmP (%)	83.79±14.82^{a}	83.51 ± 14.97^{a}	81.01± 14.12^{ab}	72.61± 25.21^{bc}	65.59 ± 28.75^{c}	71.29 ± 23.19^{c}	7.38	<0.001
	GSI (Sd/d)	3.461 ± 0.36^{a}	3.48 ± 0.36^{a}	3.45 ± 0.46^{a}	2.76 ± 1.12^{bc}	2.60 ± 1.25^{c}	3.01 ± 0.77^{b}	12.27	<0.001
	ESI (Sdl/d)	2.23 ± 0.26^{a}	2.16 ± 0.31^{a}	2.08 ± 0.36^{a}	1.70 ± 0.80^{b}	1.59 ± 0.85^{b}	1.82 ± 0.51^{b}	11.92	<0.001
BFC	SSL (mm)	82.72±13.70^{a}	81.75 ± 15.01^{a}	77.86 ± 13.46^{b}	69.46 ± 13.53^{c}	64.33 ± 13.41^{c}	78.60 ± 14.45^{b}	13.66	<0.001
	SDW (g)	0.35 ± 0.21	0.34 ± 0.21	0.33 ± 0.16	0.33 ± 0.15	0.32 ± 0.15	0.32 ± 0.17	1.64	0.145
	GnP (%)	85.90±10.39^{a}	84.61 ± 10.61^{a}	83.48 ± 13.33^{a}	62.26 ± 29.42^{c}	59.64 ± 31.87^{c}	80.12 ± 11.87^{b}	16.25	<0.001
	EmP (%)	78.24±16.68^{a}	74.22 ± 15.50^{a}	72.72 ± 18.12^{a}	57.38 ± 31.14^{c}	54.16 ± 34.30^{c}	68.88 ± 23.12^{b}	10.25	<0.001
	GSI (Sd/d)	3.34 ± 0.39^{a}	3.37 ± 0.33^{a}	3.18 ± 0.49^{b}	2.54 ± 1.19^{c}	2.44 ± 1.27^{c}	3.00 ± 0.59^{b}	12.89	<0.001
	ESI (Sdl/d)	1.97 ± 0.31^{a}	1.89 ± 0.26^{a}	1.78 ± 0.34^{b}	1.37 ± 0.75^{c}	1.27 ± 0.81^{c}	1.53 ± 0.53^{b}	15.08	<0.001

[1] GnP : germination percentage, GSI : Germination speed index, EmP : emergence percentage, ESI : Emergence speed index, SSL : seedling shoot length, SDW : Seedlings dry weight of, Sd/d : seeds/day et Sdl/d : seedlings/day, RT: room temperature

[2] In each row, the values with the same superscript letter are not significantly different from each other

Global effect of conservation duration: Seed viability and produced seedlings vigour significantly ($P < 0.001$) decreased during storage (from 0 to 6 months) in both oleaginous cultivars RFC and BFC of *Lagenaria siceraria* (**Table 3**). Thus, after 6 months of storage, seed germination percentage decreased from 93.88 ± 5.68 to 79.27 ± 11.98% and germination speed, from 3.74 ± 0.34 to 2.95 ± 0,68 seeds / day in RFC cultivar. That was the same for the seeds GC cultivar which viability significantly dropped during storage. Thus, seeds viability decreased with the shelf life. The seedling emergence percentage, emergence speed, length and dry weight decreased significantly with the shelf life (from 0 to 6 months). Thus, the control seeds (0 month) produced the most vigorous seedlings while those kept longer (for 6 months) produced the least vigorous. Seedling vigour decreased during the first 6 months of storage.

Table 3. Influence of seed shelf life on seed viability and seedling vigour parameters in both oleaginous cultivars of *Lagenaria siceraria*.

Cultivar	Parameters[1]	seed shelf life (conservation time)				Statistics[2]	
		0 month (Control)	**2 months**	**4 months**	**6 months**	***F***	***P***
RFC	SSL (mm)	84.89 ± 6.66[a]	76.03 ± 11.62[b]	68.76 ± 26.89[c]	59.16 ± 10.81[d]	505.75	<0.001
	SDW (g)	0.34 ± 0.07[a]	0.26 ± 0.07[b]	0.24 ± 0.08[c]	0.25 ± 0.04[c]	418.42	<0.001
	GnP (%)	93.88 ± 5.68[a]	82.84 ± 12.09[b]	71.66 ± 21.22[c]	79.27 ± 11.98[b]	48.09	<0.001
	EmP (%)	91.94 ± 5.58[a]	76.87 ± 14.00[b]	64.58 ± 26.28[c]	61.45 ± 22.19[c]	58.92	<0.001
	GSI (Sd/d)	3.74 ± 0.34[a]	3.14 ± 0.47[b]	2.45 ± 1.08[b]	2.95 ± 0.68[c]	61.92	<0.001
	ESI (Sdl/d)	2.40 ± 0.25[a]	1.92 ± 0.35[b]	1.48 ± 0.74[d]	1.70 ± 0.37[c]	73.03	<0.001
BFC	SSL (mm)	89.51 ± 4.61[a]	73.96 ± 9.41[b]	66.77 ± 13.25[c]	63.56 ± 10.96[d]	1900.77	<0.001
	SDW (g)	0.39 ± 0.22[a]	0.28 ± 0.05[b]	0.27 ± 0.08[b]	0.25 ± 0.03[c]	174.45	<0.001
	GnP (%)	93.88 ± 5.68[a]	82.84 ± 12.09[b]	71.66 ± 21.22[c]	79.27 ± 11.98[b]	48.09	<0.001
	EmP (%)	91.94 ± 5.58[a]	76.87 ± 14.00[b]	64.58 ± 26.28[c]	61.45 ± 22.19[c]	58.92	<0.001
	GSI (Sd/d)	3.74 ± 0.34[a]	3.14 ± 0.47[b]	2.45 ± 1.08[c]	2.95 ± 0.68[b]	61.86	<0.001
	ESI (Sdl/d)	2.40 ± 0.25[a]	1.92 ± 0.35[b]	1.48 ± 0.74[c]	1.70 ± 0.37[b]	73.03	<0.001

[1] GnP : germination percentage, GSI : Germination speed index, EmP : emergence percentage, ESI : Emergence speed index, SSL : seedling shoot length, SDW : Seedlings dry weight of, Sd/d : seeds/day et Sdl/d : seedlings/day, RT: room temperature

[2] In each row, the values with the same superscript letter are not significantly different from each other

Combined effect of drying temperatures and storage conditions over time: Whatever was the drying temperature (16, 30 and 40 ° C), seed viability of both cultivars (RFC and BFC) under the 6 storage conditions [-18° C, 4° C, room temperature (RT: 24 to 30 ° C): control, RT + ash, smoke (50 to 60 ° C) once / week + RT and smoke (50 to 60° C) twice / week + RT)] and vigour of produced seedlings generally decreased during storage (2, 4 and 6 months). Since the three drying temperatures had the same effect on seed viability and produced seedling vigour, the values of studied parameters were combined and only means are presented without taking into account these temperatures. For example in BFC, the storage of dried seeds after 6 months decreased significantly ($P < 0.001$) their germination percentage from 93.88 ± 5.68 to 79.27 ± 11.98 % and germination speed from 3.74 ± 0.34 to 2.95 ± 0.68 seeds / day. Also in RFC, seed viability fell significantly during storage. The highest performances of emergence percentage, emergence speed, seedling length and dry weight were recorded with control seeds (0 month) and the lowest, with seedlings from seeds kept longer i.e. for 6 months (**Figures 3, 4, 5, 6, 7 and 8**). Seedling vigour therefore decreased overall during the first 6 months of storage.

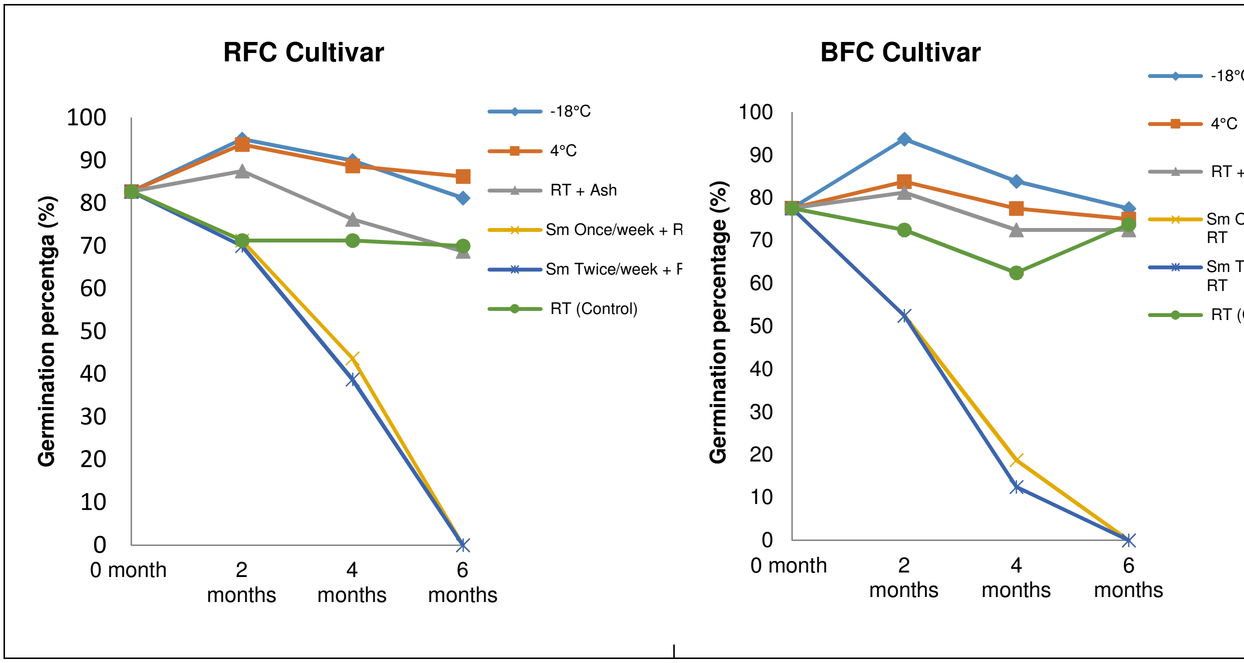


Figure 3. Curves of seed germination percentage variation during conservation of both cultivar of *L. siceraria*

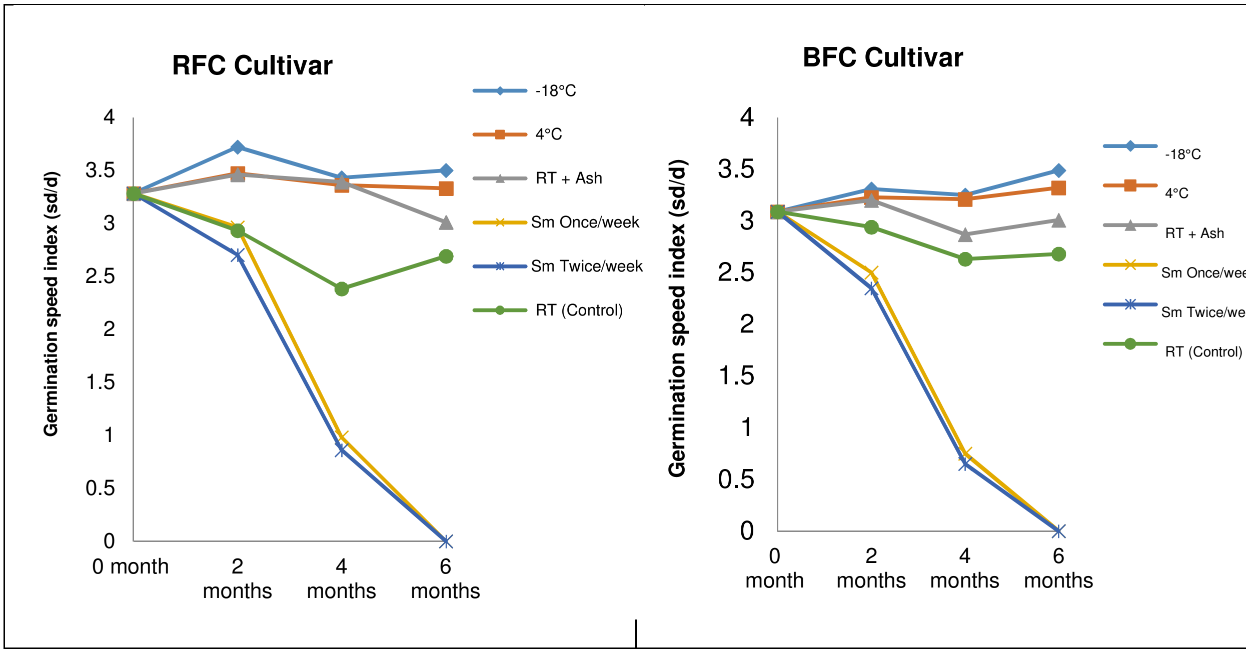


Figure 4. Curves of seed germination speed variation during conservation of both cultivars of *L. siceraria.*

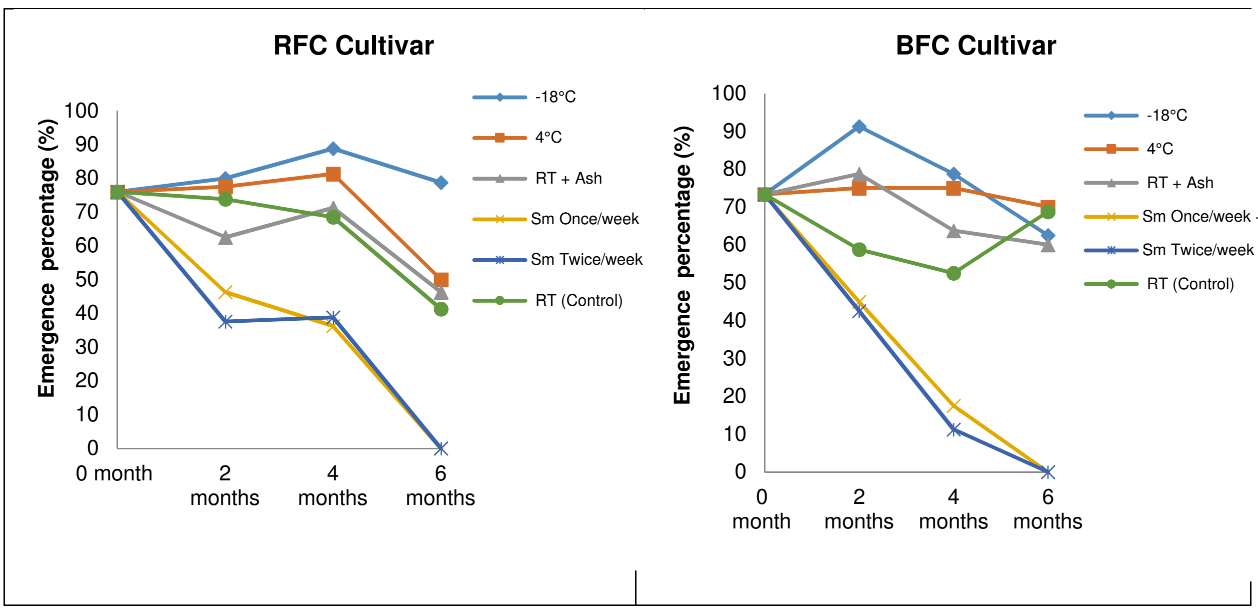


Figure 5. Curves of seedlings emergence percentage variation during seeds conservation of both cultivar of *L. siceraria*

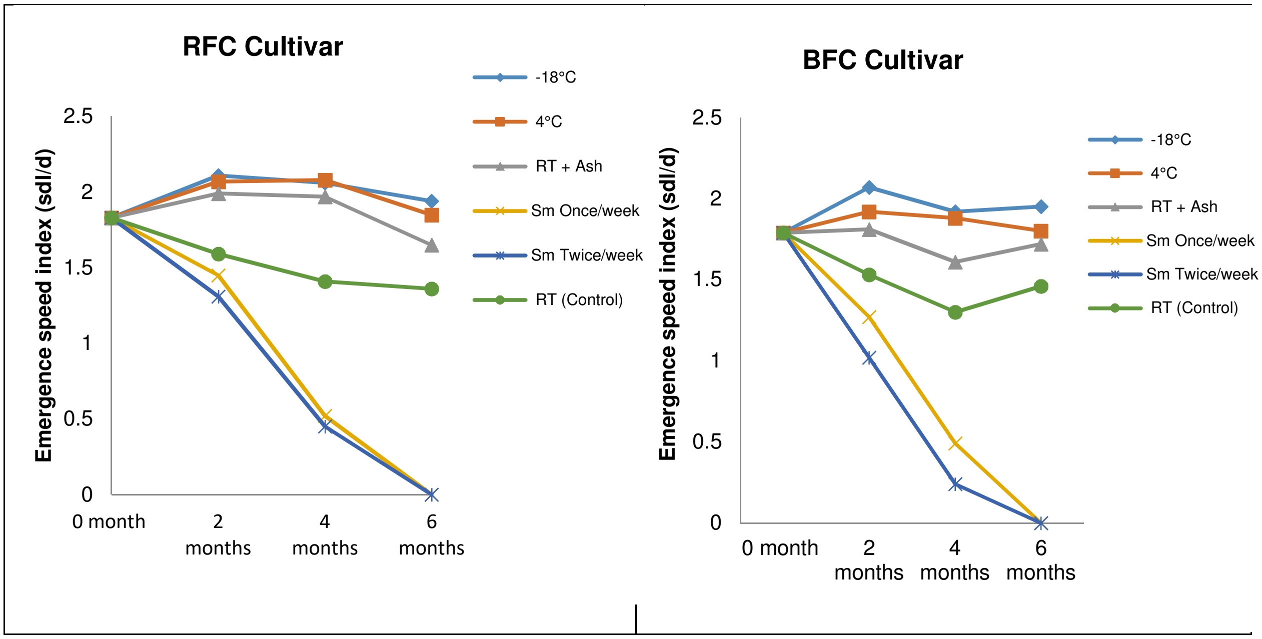


Figure 6. Curves of seedlings emergence speed index variation during seeds conservation in both cultivars of *L. siceraria*

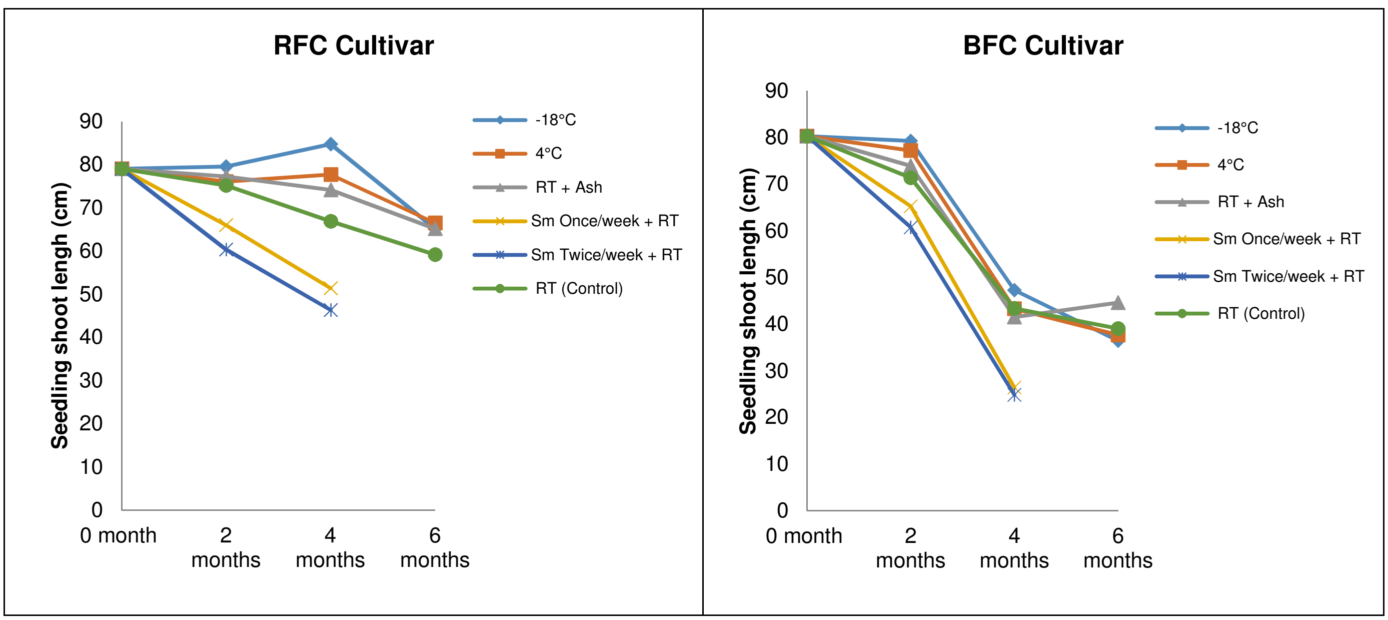


Figure 7. Curves of seedlings shoot length evolution during seeds conservation in both cultivars of *L. siceraria*

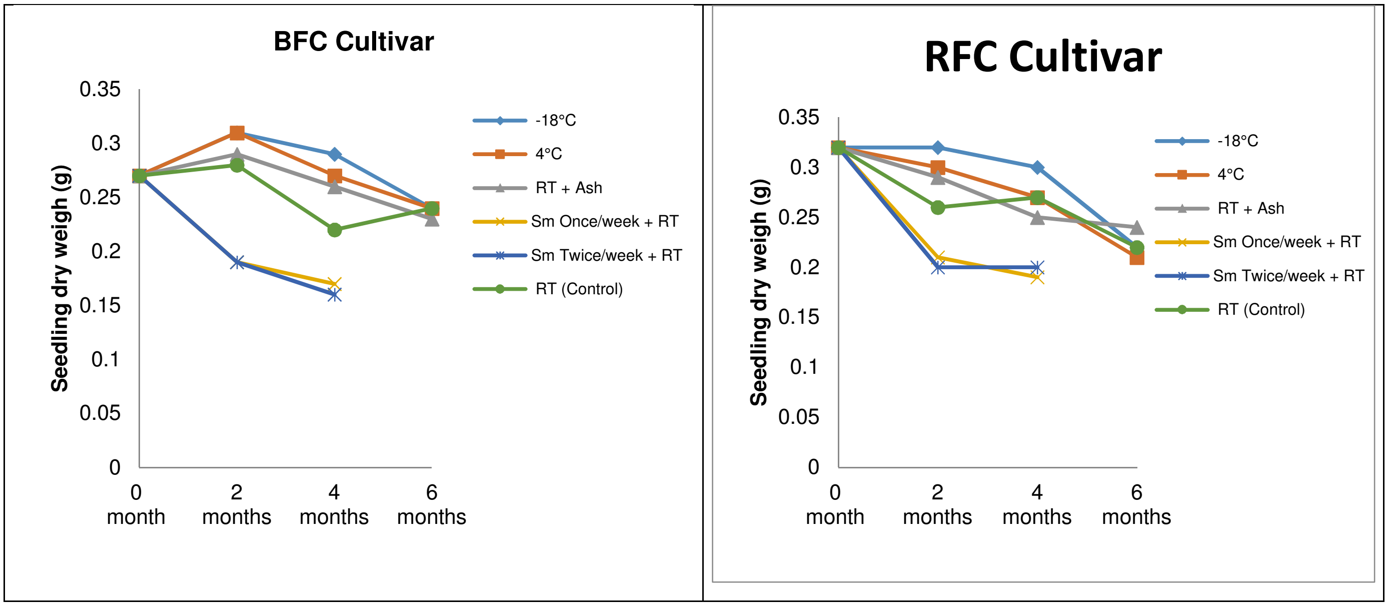


Figure 8. Curves of seedlings dry weight variation during seeds conservation in both cultivars of *L. siceraria*

DISCUSSION

Seed drying is a prerequisite for their conservability (Ellis & Roberts, 1980). The drying efficiency depends on several factors, the most important being temperature because it controls the seed moisture content (Côme, 1975; Ellis *et al.*, 1988; Usberti & Gomes, 1998). This study showed that drying temperature reduced *Lagenaria siceraria*'s seeds moisture content while increasing the initial vigour of the produced seedlings. Also during conservation, decreasing temperature reduced seed viability and seedling vigour decreases. Drying seeds to optimum moisture content before storage is essential to minimize their deterioration due to microorganisms and endogenous respiration (Dey *et al.*, 1999). After drying, the moisture content of studied seeds ranged from 8.93 to 7.14% in both oilseed cultivars (RFC and BFC) of *L. siceraria*. This result is similar to that obtained by Vodouhé *et al.* (2008) on the seeds drying in the same species (*L. siceraria*). These authors observed that these seeds final moisture content was between 9.5 and 4.6 % following the drying type (sun or silicate gel) in this case. Despite this relatively low moisture content, the initial viability of dried seeds at these temperatures was relatively high with a germination percentage of 85% for RFC cultivar and 80% for the cultivar BFC. These values are very closer to the 85% threshold recommended by Ellis *et al.* (1985) for good conservation. According to these researchers, orthodox seeds can be dried to low moisture content without great damage to embryo while their viability increases. Our results proved that the oleaginous seeds of *L. siceraria* are orthodox and the drying temperatures used are safely on their relatively high initial viability (Ellis & Hong, 2006). Furthermore, these seeds moisture content significantly dropped (from 8.93 to 7.14%) with the increase of drying temperature (from 16° C to 40° C). However viability of dried seeds was not affected by the decrease of their moisture content with the drying temperature. This could be explained by full maturity of the seeds used for experiment. In previous study, we showed that when *L. siceraria* seeds are already mature, they are not affected by drying (Yao *et al.*, 2012). Furthermore, Bankole *et al.* (2005) obtained similar result on the seeds of a cucurbit (*Colocynthis citrullus* L.). According to these authors, the discriminating effect of drying temperature through variation of seeds moisture content would affect their viability only if they are still immature. Nevertheless, in both cultivars of *L. siceraria*, the decrease of seeds moisture content following drying temperature improved vigour of produced seedlings. This vigour improvement can be explained by an increasingly significant drop in the number of microorganisms harmful to the seedlings emergence with the increase of drying temperature. According to Bankole *et al.* (2006), a seed drying in cucurbits is one of the favourable moments of their contamination by harmful microorganisms. In addition, Hamman *et al.* (2002) noted that low emergence of seedling is not always due to a drop in seeds viability, but rather to a drop in seedling growth; which prevents them to emerge to soil the surface. During storage, viability of the dried seeds and the vigour of produced seedlings significantly decreased with both storage temperature and duration. The storage temperature affected considerably seeds viability and the produced seedlings vigour of *L. siceraria*. Viability and vigour were maintained at low temperatures (-18 ° C and 4 ° C), while they were greatly reduced at relatively high temperatures (50 to 60 ° C). Maintaining low temperature viability has already been reported by Ellis and Hong (2006) with seeds of red clover (*Trifolium pratense* L.) and alfalfa (*Medicago sativa* L.), two orthodox species stored at -20 ° for 12 years in watertight structures. Moreover, according Hong and Ellis (1996), seed viability maintenance at very low temperatures (-20 to 0° C) is possible. For this, the seeds moisture content must be sufficiently low (under 13% for orthodox oilseed species). Seed low moisture content requirement for a good low temperature storage achievement, is explained by the fact that presence of water in cell promotes the formation of ice crystals in the vacuoles; which destroys the integrity of the seed cells (Theocharis *et al*, 2012). The low viability and vigour obtained with smoked seeds could be explained by the smoke temperature. Indeed, the relatively high and variable temperature (ranging from 50 to 60 ° C) of produced smoke could have caused embryo death in several seeds. The smoke effect, usually beneficial, would be compromised by its application temperatures (Ahmed *et al*., 2006). Seeds smoking being a drying technic (Bankole *et al*., 2005), smoked seeds could have lost more water as if they were still being dried. Furthermore, according to Ellis *et al.* (1986), a decrease of orthodox species seeds moisture content during drying, improves their longevity. However, there is a water content limit below which any additional drying is damaging to the sustainability (Ellis *et al*., 1988). *L. siceraria* seeds drying, during smoking, could have caused a drop in their moisture content below this limit. Probably, the optimal moisture content already reached with the different controlled drying temperatures (16, 30 and 40 ° C) before any conservation would be equivalent or identical to this limit. As for any other organ, seeds age with shelf life and eventually die (Al-Maskri *et al*., 2003). So, the oleaginous seeds of *L. siceraria* generally aged during the 6 months of storage since their viability and vigour of their seedlings dropped. This result is partially similar to that of Vodouhé *et al.* (2008) who noted in the "small gourd cultivar" of *L. siceraria* that the viability has slightly decreased after 6 months of conservation. Both cultivars (RFC and BFC) of *L. siceraria* would have a reaction similar to their "small gourd cultivar ". In addition, several hypotheses concerning the causes of aging of the seeds have been proposed. Among them, there are the reduction of respiratory capacity (Bino *et al*., 1998b), lipid peroxidation with free radicals as mediators, enzymes inactivation or proteins degradation, degradation of cell membranes and damage genetic (McDonald, 1999; Demirkaya *et al*., 2010). Despite the general seeds aging of *L. siceraria* both cultivars, the intensities of these viability and vigour drops were considerably reduced with the decrease in storage temperature during the 6 months of testing. Thus, whatever the drying temperature, seeds stored at low temperature (-18 ° C and at 4 ° C) exhibited the highest viability and the greatest vigour at each test time interval (2, 4 and 6 months). Slowing the aging at these low temperatures could be explained by a usual stop of the seeds harmful insects' development below 10° C (IPGRI, 1994). In addition, according to Ellis and Roberts (1980) seed's own metabolism (endogenous respiration) is considerably slowed down at low temperatures; which also slows down their aging (Dey *et al*., 1999). The seeds low viability during storage at room temperature, compared to low temperatures, could be explained by the fact that this temperature (above 25° C) naturally allows the develop of harmful insects in seeds (IPGRI, 1994). Moreover, the slightly higher viability of seeds stored in ash at this room temperature (24-30 ° C) attests that this substance slows down the development of insects associated with *L. siceraria* seeds. The smaller viability and lower vigour obtained with the smoked seeds would be due to the smoke temperature and not to pathogens and other associated insects. Indeed, in most of the seeds stored above the household's hearth, the generated smoke prevents insects and fungi from growing there (Hayma, 2004).

CONCLUSION AND APPLICATION OF RESULTS

This study of seed drying in both oleaginous cultivars (RFC and BFC) of *Lagenaria siceraria* indicates that seeds moisture content decreases with the drying temperature while of produced seedlings increases. Despite this effect of the drying temperature, dried seeds exhibit a relatively high viability; which confirms the orthodox nature of species. Hence seeds of both oleaginous cultivars can be dried at RT that is harmless for their embryo. However, during storage these seeds lose their viability. This viability loss increases when the seeds are smoked (at high temperature) while it is slowed down for seeds stored at low temperature.

Compared to the control, the aging slowing down slightly more significant with the ash indicates that this substance could be used for seeds conservation in rural areas. However, seeds should be stored at room temperature and not above fireplaces producing hot smoke.

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