Effects of season, time of fruit harvesting and after-ripening durations on the quality of 'egusi' melon [Citrullus lanatus (Thunb.) Matsum and Nakai] seed

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Abstract- A study of the after-ripening of 'egusi' melon [*Citrullus lanatus* (Thunb.) Matsun and Nakai] fruits was undertaken at the Teaching and Research farm of the University of Agriculture Makurdi in the wet and dry season productions of 2005 and 2007. The aim was to monitor its effects on seed quality. Fruits were harvested at two leaf colour stages [i.e. when leaves started turning yellow (LTY), and when all leaves were dry (ALD)]. Whereas, some of the fruits were processed immediately, others were left to after-ripen for seven and 14 days respectively before processing. Results revealed that fruits from plants harvested when all plant leaves were dry (ALD) were significantly heavier, contained significantly more seeds and produced higher seed yield. Seed yield was generally higher in the wet than in the dry season. There was significant increase in 100-seed weight and germination of seeds from fruits after-ripened for seven and 14 days. Seeds from after-ripened fruits also stored better than from non-after-ripened fruits. It was therefore concluded that *Citrullus lanatus* should be harvested when all leaves are dry, harvested fruits should be stored to after-ripen for about seven days and seed crop should be preferably produced during the wet season.

I. INTRODUCTION

Egusi' melon [*Citrullus lanatus* (Thunb.) Matsun and Nakai] is a protein rich food used mainly as a soup condiment in most West African countries. Its uses are however, highly diversified some of which include oil extraction and the varied medicinal uses of the white often bitter pulp (Schippers, 2000). 'Egusi' melon is a fruit vegetable whose seed germination ability has been a major problem to farmers over the years. Farmers resort to use of high seed rate and further thinning when seedling emergence is impressive. This practice is not only labourious but also wasteful. There has been no recommended harvest age for 'egusi' melon seed crop. Farmers therefore harvest at different ages depending on the level of pressure on the land. Whereas others harvest as soon as the leaves senesce, others do not gather the fruits until much later even to a stage that weeds overtake the farm. Even after harvest, fruits are subjected to differing seed extraction treatments. While others break the fruits immediately after collection to initiate the decomposition process, others wait until they are less busy from other demanding assignments. Determination of an accurate time of harvest has been reported as being a major factor in ensuring high seed quality of some crops. (TeKrony *et al.*, 1980; Oladiran and Kortse, 2002; Demir *et al.*, 2004; Khatun *et al.*, 2009). In addition, post harvest dry storage of fruits (also referred to as after-ripening) has also been reported as having the ability to improve or cause negetive impacts on the quality of seeds. (Demir and Ermis, 2004; Commander *et al.*, 2009; Passam *et al.*, 2010).

This study was therefore undertaken to determine what effects, the different harvest stages have on melon seed quality and to determine if after-ripening produces a positive or negative effect on melon seed quality.

II. MATERIALS AND METHODS

Early and late season crops of 'egusi' melon [*Citrullus lanatus* (Thunb.) Matsum and Nakai] were produced at the Teaching and Research farm of the University of Agriculture Makurdi in 2005 and 2007. Planting was done on 4^{th} May and 2^{nd} September in 2005, and on 25^{th} April and 1^{st} September in 2007 for the early and late season crops respectively. Bulk crop was established and harvesting of fruits were done at two different colour stages i.e. when leaves started turning yellow (LTY) and when all the leaves dried (ALD). Harvests were conducted at 80 and 100 days respectively in respect of LTY and ALD stages. Fruits harvested at each of the two leaf colour stages were divided at random into three lots. Fruits of the first lot were broken the same day to initiate the decomposition process (control - 0 day after-ripening duration). In the second lot, fruits were allowed to after-ripen at ambient temperature for seven days while those of the third lot were subjected to after-ripening duration of 14 days before breakage. The seeds were thereafter, extracted washed and sun dried. Data were collected on fruit weight, number of seeds per fruit, and dry seed weight per fruit. Furthermore, data were also collected on 100-seed weight before germination tests were conducted. The experiment was therefore a 2 x 3 factorial in each season/year.

Seeds produced in 2005 were packed in polyethylene bags and stored in an ambient environment (approx. $32^{o}C$ and 40% relative humidity). Germinability was then tested after one, two, and three years of storage. Germination tests made immediately before and during storage, were conducted on four replicates of 50 seeds each, spread over distilled water-moistened absorbent paper in Petri dishes and incubated at $30^{0}C$ for 28 days. Counts were taken every other day.

III. RESULTS

Citrullus lanatus data was averaged over the two years of production and analysis indicated that leaf colour (LC) significantly influenced (P < 0.05) all parameters in 2005 (Table 1). After-ripening duration (AR) significantly influenced 100-seed weight and germination percentage. Furthermore, planting season (S) significantly affected fruit weight, number of seeds per fruit, seed weight per fruit, 100-seed weight and germination percentage. The interaction between AR and LC significantly influenced 100-seed weight only while AR x S interaction only influenced seed weight per fruit. In addition, LC x S interaction significantly influenced fruit weight, dry seed weight per fruit and germination percentage. AR x LC x S interaction was non-significant.

In 2007, AR significantly influenced all parameters except fruit weight. LC also significantly affected all parameters except 100-seed weight and germination percentage. Furthermore, planting season had significant effects on all parameters except 100-seed weight. The interaction between LC and S significantly influenced all parameters except number of seeds per fruit and 100-seed weight while AR x LC and AR x S interactions had significant effects on 100-seed weight. AR x LC x S interaction was non-significant.

Table 1 Mean square values for some attributes of *Citrullus lanatus* fruits produced in the two seasons of 2005 and 2007, harvested at LTY and ALD stages and subjected to different after-ripening durations.

Sources of variation	Fruit weight	No.of seeds/fruit	Dry seed wt./fruit	100-seed wt.	Germ.%
2005					
Replications	0.0028 ns	2263.1 ns	5.525 ns	0.2049 ns	111.90 ns
After-ripening (AR)	0.0019 ns	2382.7 ns	6.499 ns	1.8849 **	692.53 **
Leaf colour (LC)	0.3249 **	12844.4 **	741.382 **	51.1225 **	1593.7 **
Season (S)	0.2209 **	6507.1 *	327.067 **	15.3664 **	2428. **
AR x LC	0.0034 ns	1693.4 ns	2.865 ns	1.4332 *	73.16 ns
AR X S	0.0001 ns	182.5 ns	12.053 *	0.0782 ns	168.74 ns
LC x S	0.1024 **	0.4 ns	5.406 ns	3.8025 **	110.69 ns
AR x LC x S	0.0048 ns	697.9 ns	1.237 ns	0.3252 ns	19.72 ns
Error	0.0085	887.6	2.315	0.2987	60.43
Total	40.6221	6.5644	0.0296	0.4131	0.0056
2007					
Replications	0.2347 ns	357.7 ns	7.517 ns	1.042 ns	57.25 ns
After-ripening (AR)	0.1998 ns	2941.4 **	47.988 **	1.435 ns	1115.6 **
Leaf colour (LC)	1.0575 *	11484.7 **	321.844 **	22.562 **	100.17 ns
Season (S)	1.8632 **	22250.7 **	90.757 **	4.203 ns	1961.7 **
AR x LC	0.1288 ns	215.5 ns	1.542 ns	1.086 ns	55.19 ns
AR X S	0.1829 ns	803.0 ns	7.478 ns	1.398 ns	2.38 ns
LC x S	0.8070 *	1431.4 ns	156.834.**	6.167 *	316.42 *
AR x LC x S	0.2987 ns	821.9 ns	0.726 ns	0.210 ns	73.23 ns
Error	0.1709	476.5	7.393	1.284	50.67
Total	3.6553	6.2579	0.0406	0.4894	0.0070

ns, *,** = non significant or significant at P = 0.05 and P = 0.01, respectively, AN0VA

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In 2005, the superiority of fruits harvested at ALD stage over those at the LTY stage was only observed in the wet season (Table 2). Whereas in the wet season, fruits were significantly heavier from plants harvested when all plant leaves were dry (ALD), compared with the value obtained in fruits harvested when leaves turned yellow (LTY); no such difference was recorded in the dry season production.

In 2007, there was no significant difference between LTY and ALD in both planting seasons. However, ALD fruits harvested during the wet season were significantly heavier than the LTY and ALD fruits produced in the dry season.

Table 2 Interaction effects of season and leaf colour on fruit weight (kg) of *Citrullus lanatus* harvested at the LTY and ALD stages in the wet and dry seasons of 2005 and 2007 and subjected to different after-ripening durations.

		Production year	
Season (s)	**Leaf colour (LC)**	**2005**	**2007**
Wet	**LTY**	0.73 b	1.18 ab
	ALD	1.02 a	1.82 a
Dry	**LTY**	0.99 a	1.03 b
	ALD	1.07 a	1.07 b

Means followed by the same alphabet in each year and LC / S are not significantly different using DMRT at 5% probability level.

In both years, fruits harvested at the ALD stage contained significantly more seeds than those harvested at the LTY stage (Table 3). However, whereas dry season fruits contained significantly more seeds than those produced in the wet season in 2005, the reverse was the case in 2007. Furthermore, after-ripening of fruits for seven days resulted in significantly greater number of seeds per fruit than other after-ripening durations.

Significantly higher seed yield was obtained at the ALD than at the LTY stage in 2005. In addition, fruits produced in the dry season yielded more seed than those in the wet season.

Table 3 Effects of leaf colour, season and after-ripening duration in 2005 and 2007 on the number of seeds per fruit of *Citrullus lanatus.*

	Season		
Leaf colour (LC)	**Wet**	**Dry**	**Mean**
2005			
LTY	168	195	182 b
ALD	205	233	219 a
Mean	187 b	214 a	
After-ripening (AR)	ns		
2007			
LTY	208	171	190 b
ALD	256	194	225 a
Mean	232 a	183 b	
AR Means (days)			
0	196 b		
7	225 a		
14	201 b		

Means followed by the same alphabet in each year and LC / S are not significantly different using DMRT at 5% probability level.

Table 4 shows that whereas AR did not significantly affect seed yield in the wet season, fruits after-ripened for seven days following dry season production, yielded more seed than those not after-ripened at all or after-ripened for 14 days.

Table 4 Interaction effects of after-ripening duration and season on dry seed weight (g) of *Citrullus lanatus* in 2005.

After-ripening duration (days)	Season	Dry seed weight (g)
0	**Wet**	17.84 c
	Dry	21.97 b
7	**Wet**	17.18 c
	Dry	25.31 a
14	**Wet**	17.13 c
	Dry	22.96 b

Means followed by the same alphabet in each year and AR / S are not significantly different using DMRT at 5% probability level.

In 2007, though seed yield at ALD stage was generally significantly higher than at the LTY stage and yield was generally higher in the wet than in the dry season the trend may not always be consistent. For example, as revealed in Table 5, in the wet season production, ALD value was significantly greater than LTY value whereas the differences between the values for these two leaf stages were not significant in the dry season production. Similarly, whereas there was no significant season's effect when fruits were harvested at the LTY stage, seed weight was significantly higher in the wet than in the dry season when fruits were harvested at the ALD leaf stage.

Table 5 Interaction effects of Leaf colour and season on dry seed weight (g) of *Citrullus lanatus* in 2007.

Leaf colour	Season	Dry seed weight (g)
LTY	**Wet**	19.40 b
	Dry	20.40 b
ALD	**Wet**	29.56 a
	Dry	22.21 b

Means followed by the same alphabet in each year and LC / S are not significantly different using DMRT at 5% probability level.

Although after-ripening of fruits for seven and 14 days generally increased 100-seed weight, the differences were only significant when harvesting was done at the LTY stage; even at this stage, the differences in the values obtained following seven and 14 days after-ripening was not significant (Table 6).

Table 6 Interaction effects of AR and LC, and LC and S on 100-seed weight (g) of *Citrullus lanatus* in 2005.

	Season	

AR(days)	LC	Wet	Dry	LC mean	AR mean
0	**LTY**	8.50	8.60	8.55 c	
	ALD	10.57	12.2	11.65 a	
					10.10 b
7	**LTY**	9.43	10.33	9.88 b	
	ALD	10.70	12.49	11.60 a	
					10.74 a
14	**LTY**	9.23	10.14	9.67 b	
	ALD	11.03	12.95	11.99 a	
Season means		9.90b	11.21 a		10.83 a
LC means					
LTY	9.36 b				
ALD	11.75 a				

Means followed by the same alphabet in each year and AR/LC / S are not significantly different using DMRT at 50% probability level.

Fruit production during the dry season may not always yield seeds that are heavier than in the wet season. Table 7 shows that seeds obtained at the ALD stage in the wet season of 2007 were heavier than the dry season seeds obtained at the LTY stage.

Table 7 Effects of LC and S on 100-seed weight (g) of *Citrullus lanatus* in 2007.

		Season		
Leaf colour	**After-ripening duration**	**Wet**	**Dry**	**Leaf colour mean**
LTY	**0**	9.63	11.57	
	7	11.43	12.07	
	14	10.53	12.50	
				11.29 b
ALD	**0**	13.03	12.70	
	7	13.47	12.73	
	14	12.33	12.97	
				12.87 a
	Season means	11.74 b	12.42 a	

Means followed by the same alphabet in each year and LC / S are not significantly different using DMRT at 5% probability level

It is however obvious from Table 8 that whereas LC did not influence 100-seed weight significantly in the dry season production, seeds were heavier when fruits were harvested at the ALD stage in the wet season. In addition, whereas the season of production did not significantly affect 100-seed weight in fruits harvested at the ALD stage, seeds were heavier in the dry than in the wet season when harvesting was done at LTY stage.

Table 8 Interaction effects of leaf colour and season on 100-seed weight of *Citrullus lanatus* in 2005 and 2007.

		100-seedweight (g)	
Leaf colour	**Season**	**2005**	**2007**
LTY	**Wet**	**9.03 c**	**10.53 b**
	Dry	**9.69 c**	**12.04 ab**
ALD	**Wet**	**10.77 b**	**12.94 a**
	Dry	**12.72 a**	**12.80 a**

Means followed by the same alphabet in each year and LC / S are not significantly different using DMRT at 5% probability level.

Seeds from fruits after-ripened for seven and 14 days significantly germinated better than those from non after-ripened fruits (Table 9). Also harvesting of fruits at the ALD stage resulted in significantly higher seed germination than harvesting at the LTY stage. Furthermore, dry production gave significantly better germination season.

Table 9 Effects of after-ripening durations (AR), leaf colour (LC), and season (S) on the germination of *Citrullus lanatus* in 2005.

		Season		
AR (days)	**LC**	**Wet**	**Dry**	**AR Means**
0	**LTY**	53	66.5	
	ALD	70.5	80.5	
				68
7	**LTY**	60.5	91.5	
	ALD	77.5	95.5	
				81
14	**LTY**	56	86.5	
	ALD	88	97.5	
				82
Season mean		68	86	

In 2007, AR, S as well as LC by S interaction significantly influenced seed germination level (Table 10). After-ripening of fruits for 14 days resulted in a significant improvement in germination over after-ripening for seven days which in turn gave seeds that significantly germinated better than in fruits that were not after-ripened. Table 11 shows that whereas leaf colour at harvest did not significantly affect the germination of the seeds produced in the dry season, seeds from fruits harvested at the ALD stage germinated significantly higher than those harvested at the LTY stage in the wet season.

Table10. Interaction effects of leaf colour (LC) and season on the germination of *Citrullus lanatus* in 2007.

Leaf colour	Season	Percentage germination
LTY	**Wet**	47 b
	Dry	76 a
ALD	**Wet**	60 ab
	Dry	75 a

Means followed by the same alphabet in each year and DAA / S are not significantly different using DMRT at 5% probability level.

Table11. Interaction effects of leaf colour (LC) and season on the germination of *Citrullus lanatus* in 2007.

Leaf colour	Season	Percentage germination
LTY	**Wet**	47 b
	Dry	76 a
ALD	**Wet**	60 ab
	Dry	75 a

Means followed by the same alphabet in each year and DAA / S are not significantly different using DMRT at 5% probability level.

A delay in fruit harvesting until all leaves were dry resulted in improved seed germination even during storage (Figure 12). An improvement in germinability was recorded even after two years of storage. Though a decline in viability was recorded following three years of storage, values were highest from fruits harvested when all leaves were dry. In all cases, post-harvest ripening of fruits for 14 days gave the best results. Figure 13 also shows that when production was done during the dry season, early harvest resulted in poorer germination and longevity and fruit after-ripening following harvesting at the two-leaf stages resulted in better seed quality.

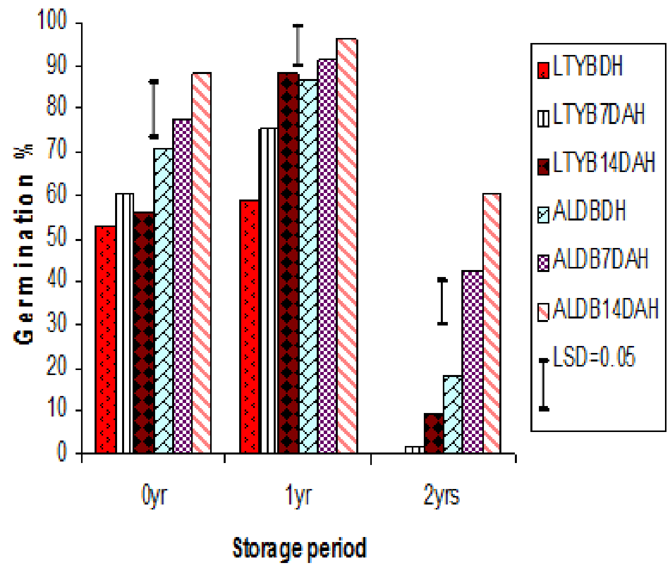

Fig. 12 Variations in percentage germination of wet season Citrullus lanatus harvested in 2005 when leaves started turning yellow and when all leaves dried and tested before storage and after storage for one and two years under ambient conditions.

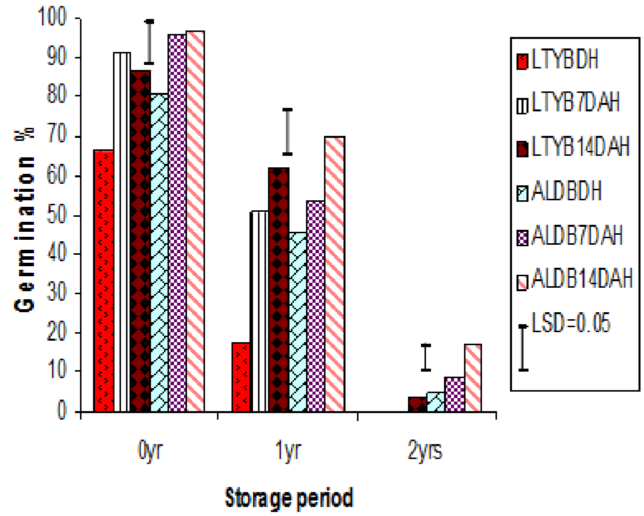

Fig. 13 Variations in percentage germination of dry season Citrullus lanatus harvested in 2005 when leaves started turning yellow and when all leaves dried and tested before storage and after storage for one and two years under ambient conditions

IV. DISCUSSION

The significant increase in the weight of fruits harvested at the ALD stage relative to that recorded at the LTY stage in the wet season of 2005 is an indication that fruit filling continued beyond the latter stage. This is in agreement with reports by Mayer et al. (1991), Goldberg et al. (1994), Raz et al. (2001) and Bentsink and Koornneef (2008) that as an embryo undergoes maturation, there is food reserve accumulation. Natrajan and Srimathi (2008) also reported an increase in Petunia pod weight with increase in days after anthesis due to the development from zygote to matured seeds. The lack of significant differences in the size of fruits harvested at the two stages in the dry season indicates that maximum fruit growth was already attained at the LTY stage and this suggests that fruits might have developed faster in the dry season.

The number of filled seeds per fruit, which were, contained more in ALD than in LTY fruits is also an indication that different seeds within a fruit do not mature at the same rate. Immature seeds would normally decompose and or float off during processing. This view agrees with that of Nielsen (1996) who reported that seeds on the same fruit may not normally be of the same age. This is expected since pollen grain may not germinate at the same rate and pollen tube growth, zygote formation and seed development and maturation may not proceed at the same rate (Silvertown, 1984; Delph et al., 1998). The improvement recorded when fruits were stored for some days before processing suggests that seed filling continued in stored fruits. This explanation agrees with that of Passam et al. (2010) who also recorded seed filling in-situ and hence higher seed weight of after-ripened fruits of eggplant. Furthermore, the higher seed yield recorded for Citrullus lanatus in the wet season of 2007 could be attributed to the lower temperature regime during fruit development. Lower temperature is known to enhance seed development (Duthion and Pigearie, 1991). The reversed trend in 2005 is an indication that other factors may be involved. If Citrullus lanatus was grown in the dry season, fruits could be harvested at any of the two leaf stages without compromising seed viability. This is in agreement with an earlier statement that seeds might have developed faster in the dry than in the wet season.

Seeds from after-ripened fruits stored better than those from the non-after-ripened ones. The increase in seed vigour that normally accompany after-ripening (Alan, and Eser, 2008; Passam, et al., 2010) might have been responsible for the improvement in longevity. The improvement in the germination percentage of seeds that were produced in the wet season and stored for one year is an indication of the presence of dormancy when seed were freshly harvested. The dormancy must have been broken with time. This is in agreement with the results recorded for watermelon by Nerson (2002) and for pepper (Capsicum annum L.) by Oladiran and Kortse (2002) in which seed germination increased with storage period. It is not known why the seed produced in the dry season behaved differently. However, the fact that the freshly harvested wet season-produced seeds exhibited some level of dormancy might be suggesting the accumulation of some germination inhibitors, which was depleted as storage, progressed (Baskin and Baskin 1998). Seed dormancy has been positively related with absicic acid (ABA) presence or the sensitivity of seeds to this phytohormone (Finch-Savage and Leubner-Metzger, 2006). The current study revealed that seedlots that exhibited greater dormancy also recorded slower deterioration during storage. This is in agreement with the findings of Debeaujon et al. (2000) and Contreras (2008) who recorded better survival in more dormant seed. Contreras (2008) attributed the trend to structural defects such as missing layers or modified epidermal layer in the less dormant seed lots.

It is concluded from this study that, fruits of Citrullus lanatus should be harvested when all leaves on the plant are dry. For higher seed quality still, harvested fruits should be stored to after-ripen for about seven days. Furthermore, seed crop of Citrullus lanatus should be preferably produced during the wet season for high seed vigour.

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