International Journal of Biochemistry Research & Review

Volume 33, Issue 5, Page 79-90, 2024; Article no.IJBCRR.116232
ISSN: 2231-086X, NLM ID: 101654445

Effect of Fruit Harvest Time on the Nutritional and Agronomic Quality of Oleaginous *Citrullus lanatus* Seeds

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJBCRR/2024/v33i5878

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/116232

Original Research Article

Received: 25/02/2024
Accepted: 29/04/2024
Published: 06/05/2024

ABSTRACT

Oilseeds of *Citrullus lanatus* are highly prized in African societies for their nutritional and socio-economic importance. In an attempt to improve their yield, remaining very low mainly due to lack of good nutritive and germinative quality seeds, the effect of fruit harvest time was studied. After growing plants of "wlêwlê" cultivar on Nangui Abrogoua University experimental site, fruits were harvested at six different times [15, 20, 25, 30, 35 and 40 days after anthesis (DAA)] then fermented to produce seeds for germination test concerning agronomic aspect and biochemical analysis for nutritional quality. Agronomically, results showed that delaying harvest time (from 15 to 40 DAA) significantly ($P < 0.001$) improved fruit weight (from 512.20 to 760.50 g) and their seed content (from

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71.75 to 230.70 seeds/fruit), as well as size (from 10.69 to 11.42 mm) and weight (from 5.16 to 6.37 g) of dry seeds what lead to their optimum viability (89.50%). Nutritionally, apart from ash which didn't vary, *C. lanatus* seeds reached their highest levels of flavonoids (0.03 mg/100g) and tannins (0.022 mg/100g) at 15 DAA, followed by protein (30.66%), lipids (56.60%) and vitamin C (2.25 mg/100g DM) ones at 35 days while dehydrating to reach the lowest moisture content (5.51%). Hence, this variety seeds reach their nutritional maturity earlier, already at 35 DAA, while their optimal germination quality occurs later at 40 DAA.

Keywords: Citrullus lanatus; harvest time; agronomic quality; biochemical parameters.

1. INTRODUCTION

Citrullus lanatus is a significant cucurbit species that comes in two varieties: the oleaginous variety known as Africa melon, or "egusi," which is commonly grown and used in Africa [1], and the watermelon form that is extensively researched in America and Europe [2]. Africa melon is grown for its inexpensive edible seeds [4,5], whereas watermelon is grown for its fresh consumable fruits [3]. In sub-Saharan Africa oleaginous types of *C. lanatus* are consumed as thickeners of a traditional soup called "pistachio soup" in Côte d'Ivoire. Several studies [6,7] showed their high richness (60% Lipids and 30% proteins). Furthermore, they constitute an important income source for farmers, mainly women, in West and Central Africa [4]. Despite the economic, social and nutritional roles tey play, these oleaginous cucurbits remain secondary crop. Indeed, very few is known about seed production system specific to this plant cultivation for its production optimization [8].

Using minimal inputs, women mostly grow oleaginous *C. lanatus* crop at small scale under traditional agro-systems conditions in Côte d'Ivoire. These cucurbits fruits are generally harvested after plants complete senescence. Because of fruiting extent, not all the fruits reach maturity before this senescence, resulting in a melting of mature and immature seeds at harvest [9]. This explains the low germination rate and poor seed yield that have been widely documented, supporting the undervaluation and neglect of this plant group. Nonetheless, oleaginous C. lanatus farming provides a reliable source of revenue in addition to meeting the immediate food demands of the family [5]. These crops high potential lead several institutions and scientific organizations, including the FAO and Biodiversity International; now recommend that efforts to increase productivity and quality of the agricultural system in developing countries be focused on them [10]. Improving production techniques for any crop requires good control of factors linked to seed quality, i.e. its biochemical composition and germination [5]. Indeed, seed germination quality strongly influences future plants yield [11]. Several factors were recognized as influencing this germination quality. Seed agronomic quality, i.e. their aptitude to germinate and produce vigorous seedlings [12,13,14] depends mainly on its physiological maturity.

It was largely demonstrated that seed attain maximal vigour and potential germinability at physiological maturity, where its filling ends [9]. According to Gupta et al. [15], optimizing the appropriate harvest time/stage for seeds is important especially in fleshy fruits like cucurbits. However, determination of optimum harvesting stage is difficult in cucurbits species that have indeterminate growth and an extended flowering period [16]. For this end, our recent study on seeds viability of oleaginous *C. lanatus* showed that fruit harvest time strongly influences seeds germination, which is optimum after 40 days after anthesis [8]. Unfortunately, the lack of biochemical analysis could not link this good seed agronomical behavior to their biochemical quality. Seed viability has therefore been studied following their biochemical composition during fruit growth for this cucurbit in order to optimize its production.

2. MATERIALS AND METHODS

2.1 Plant Material

In this study, plant material consisted of oilseed from the "wlêwlê" cultivar of *Citrullus lanatus.*

2.2 Methods

2.2.1 Production of various aged seeds

Wlêwlê cultivar of oleaginous *Citrullus lanatus* was grown during the small rainfall season (from July to December, 2021) in an isolated field (Fig. 2a) at the experimental field of Nangui Abrogoua University (Abidjan, Côte d'Ivoire). For obtaining vigorous seedlings, then good yield, field was pre-fertilized with pig manure and regularly maintained by three weeding's and one insecticidal treatment (Cypercal 50 EC). Approximately 300 pistillate flowers were tagged at anthesis (Fig. 2b), and developed fruits (Fig. 2c) from them were manually harvested by simple rupture of stalk at 15, 20, 25, 30, 35 and 40 days after anthesis (DAA). From harvested fruits, some were randomly selected and individually weighed using field balance. This allowed their mean weight and standard deviation calculation following harvest times. Then fruits were split using big kitchen knife and fermented (Fig. 2d) by packing them in a transparent plastic bag that was hidden 30 cm depth in the soil [8]. After a 10-days fermentation period [17], were manually extracted, abundantly washed (Fig. 2e) with tap water and then sun-dried at ambient air (22 to 32°C) until constant weight (Fig. 2f). Two seed lots were constituted from each harvest time: one for agronomic quality test and the other for biochemical quality. Finally 12 samples of seeds (2 lots × 6 harvest times) were sorted and sealed in aluminum foil waiting tests.

Fig. 1. Oilseeds of *Citrullus lanatus* "wlêwlê" cultivar

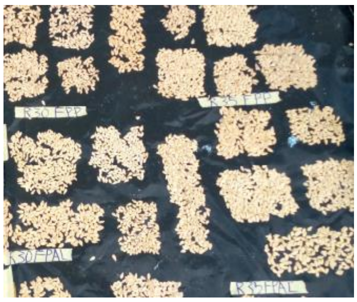
a- On field plants production

b-Female flower taged at anthesis

c-fruits harvested at precise age

d-fruit fermentation

e-seeds extraction and washing



f-seeds sun-drying

Fig. 2. Process of obtaining various aged seed of *Citrullus lanatus*

2.2.2 Nutritional quality analyses of seeds harvested at different times

2.2.2.1 Processing of Citrullus lanatus seed powder

Individual lots of *Citrullus lanatus* seeds corresponding to each harvest time (15, 20, 25, 30, 35 and 40 DAA) were sorted and cleaned free from debris or foreign bodies such as sand grains. These cleaned seeds were manually dehulled to separate fines from cakes. Each sample was ground (Fig. 3) in a Moulinex-type blender (Normandy, France). The resulting powders were stored in hermetically sealed glass jars and coded according to harvest time prior to biochemical analysis.

2.3 Biochemical Analyses

Some biochemical and physico-chemical parameters were determined. Samples were analyzed for moisture content using the [18] method. Protein content was determined using the Kjeldahl method [18]. The total lipid content of each 6-powder samples from the oil seeds of *C. lanatus* was determined using the SOXHLET method; the crude fibre content, according to the AOAC method and the ash, through incineration in a muffle burner at 500°C following the [18] method. Total phenolic compounds were extracted following [19] and assayed, based on [20]. Flavonoid content in terms of quercetin equivalents in each seed lot powder of cultivar "wlêwlê" was obtained as described by Meda et al. [21]. Total tannin content was determined using Bainbridge et al. [22] method. Ascorbic acid content was determined according to the procedure described by Pongracz et al. [23], using 2, 6-dichlorophenol indophenol.

2.3.1 Seed viability and seedling vigor tests and their data collection

Seed viability was evaluated using the laboratory seed germination test. Seeds were considered as germinated when the emerging radicle reached at least 2 mm in length (Fig. 4a). The sown seeds were surveyed daily for 14 days [24]. Seed viability was evaluated using fruit weight (FrW), seeds number per fruit (SNF), seed size (length, width and thickness), weight of 100 seeds (W100), germination percentage (GeP), germination speed index (GSI) and germination mean time (GeMT).

Seedling vigor vas evaluated on farm trial using four completely randomized blocks represented by seedbeds constituting each, one replication measuring 1.5 m × 0.5 m. Seedbeds were spaced 50 cm each other. Each seedbed contained six treatments corresponding each to fruit harvest time (15, 20, 25, 30, 35 and 40 DAA). Treatments consisted of 25 sowings spaced 3 cm. Seeds were sown on well-ploughed seedbeds to a depth of 3 cm, with single seed in each hole and the holes spaced 7 cm apart. A total of 600 seeds were sown. Seedlings were considered emerged when their two cotyledonary leaves were completely opened (Fig. 4b) [25]. Seedling vigor was examined using the following parameters: seedling emergence percentage (EmP), emergence speed index (ESI), shoot length (SSL, measured with a ruler after digging up the emerged seedling), and seedling dry biomass (SDB, measured after drying the seedling to constant weight). The GSI and ESI were calculated based on Maguire's procedure according to the following equation:

By Maguire [26]: GSI o $ESI = \frac{X_1}{N_1} + \frac{X_2}{N_2} + \cdots + \frac{X_n}{N_N}$r

where:

X1, X2, and Xn represent the numbers of germinated seeds or emerged seedling 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.

2.4 Statistical Analysis

All data collected in this study were statistically analyzed using STATISTICA 7 (Statsoft Inc, Tulsa-USA Headquarters) and XLSTAT-Pro 7.5.2 (Addinsoft Sarl, Paris-France) statistical software [27] for both biochemical and agronomic parameters. Percentage data were arcsin-transformed before analysis [28] but untransformed data were used to calculate means to present the agronomical results. One-way Analysis of variance (ANOVA 1) was performed to test the effect of fruit harvest time. When the null hypothesis was rejected for each parameter, multiple comparisons using the Least Significant Difference (LSD) were carried out test to separate the means [29]. All the tests (ANOVA and LSD) were performed at α = 0.05 significance level.

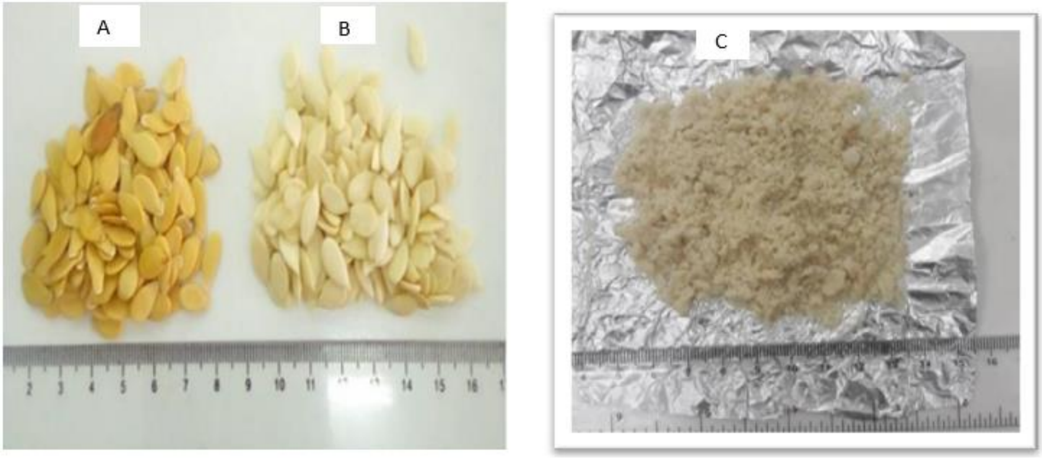
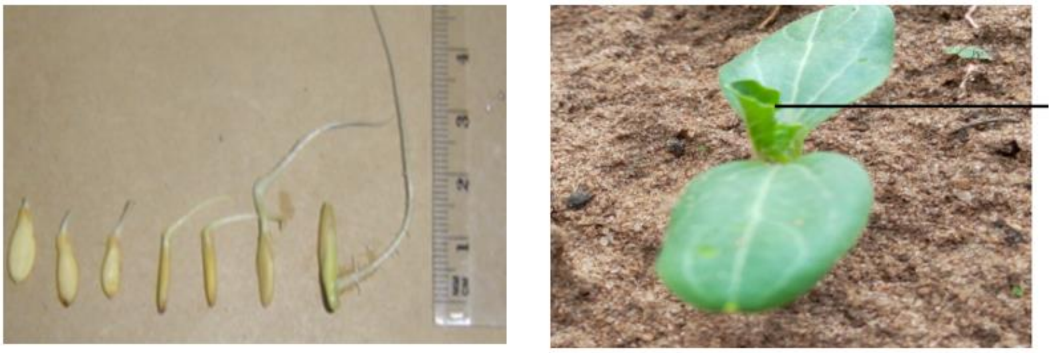


Fig. 3. Unhulled (A), hulled (B) and ground (C) seeds of *Citrullus lanatus* cultivar "wlêwlê"



a-Some steps of C. lanatus seeds germination in Petri dish
b-Seedling of C. lanatus at emergence step on farm

Fig. 4. Germination and emergence of *C. lanatus* seeds

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Effect of fruit harvest time on *Citrullus lanatus* seeds biochemical parameters

Variations of *Citrullus lanatus* seeds biochemical parameters depending on fruit harvest time are mentioned in Table 1.

3.1.1.1 Seed moisture content

Delaying fruit harvest time (from 15 to 40 DAA) resulted in a significant decrease (P < 0.001) in *C. lanatus* seed powder moisture content (from 5.51 to 3.55%), which stabilised from the 35th to the 40th DAA.

3.1.1.2 Proteins content

Delaying berry harvesting (from 15 to 40 DAA) led to a significant increase in *oleaginous C. lanatus* seeds protein content (from 27.95 to 30.50 %). In this *C. lanatus* cultivar, protein content is optimal at 35 DAA.

3.1.1.3 Seed lipids content

In the *C. lanatus* seeds, lipid content rose very significantly from 52.23 to 56.60% when harvesting was delayed (from 15 to 35 DAA), then fell to 54.17% once the crop was delayed from 35 to 40 DAA. During fruit formation, seeds accumulate lipids reaching optimum levels around the 35th DAA before falling towards the 40th DAA.

3.1.1.4 Fibers content

Delaying harvest (from 15 to 30 days after anthesis) lead to an increase in *C. lanatus* seed fibers content (from 10.29 to 26.26 %) (Fig. 4). In contrast, extending harvests from 30 to 40 DAA resulted in a drastic fall (from 26.26 to 14.82 %) in their fiber content. In this *C. lanatus* cultivar, seed reach their optimal fiber content at 30 DAA.

Table 1. Variations of *Citrullus lanatus* seeds biochemical parameters following fruit harvest time

Seed biochemical content	Fruit harvest time (days after anthesis)						Statistics	
	15 DAA	**20 JAF**	**25 DAA**	**30 DAA**	**35 DAA**	**40 DAA**	***F***	***P***
Moisture (en %)	5.51 ± 0.98^{d}	5.51 ±1.03^{d}	4.45 ±0.96^{c}	3.78 ±0.78^{b}	3.57 ±0.95^{a}	3.55 ± 1.01^{a}	12.53	< 0.001
Protein (%)	27.95 ± 6.47^{a}	28.86±8.39^{b}	29.13±9.41^{b}	30.02±8.33^{c}	30.66±3.58^{d}	30.5±5. 73^{d}	85.13	< 0.001
Lipids (%)	52.23 ± 9.46^{a}	52.22±8.37^{a}	53.21±6.25^{b}	55.06±9.58^{c}	56.6±9.15^{e}	54.17±8.52^{d}	70.68	< 0.001
Fibers (%)	10.29 ± 3.37^{a}	15.26±4.38^{b}	20.83±2.88^{d}	26.26±3.68^{e}	17.37±3.89^{c}	14.82±3.25^{b}	39.23	< 0.001
Ash (%)	3.59 ± 0.88^{a}	3.47±1.06^{a}	3.56±0.98^{a}	3.47±1.2^{a}	3.00 ± 1.03^{a}	3.65±0.79^{a}	89. 63	< 0.001
Total phenols (mg/100 g DM)	0.081±0.001^{b}	0.084±0.003^{b}	0.096±0.002^{c}	0.093±0.001^{c}	0.097±0.002^{c}	0.054±0.00^{a}	34.73	< 0.001
Flavonoids (mg/100g DM)	0.030±0.005^{c}	0.030±0.002^{c}	0.030±0.003^{c}	0.020±0.001^{b}	0.010±0.004^{ab}	0.010±0.001^{a}	27.16	< 0.001
Tannins (mg/100g DM)	0.08±0.002^{c}	0.020±0.003^{c}	0.017±0.001^{abc}	0.008±0.004^{b}	0.006±0.002^{ab}	0.006±0.001^{a}	49.29	< 0.001
Vitamin C (mg/100g DM)	1.55±0.011^{a}	2.00±0.017^{b}	2.00±0.023^{b}	2.25±0.032^{c}	2.25±0.018^{c}	2.00±0.011^{b}	36.45	< 0.001

Table 2. Effects of harvest time on fruits, seed viability and seedlings parameters in oleagnionous *Citrullus lanatus*

Agromiccal parameters		**Fruit harvest time (Days after anthesis)**						**Statistiques*****	
		15 DAA**	**20 DAA**	**25 DAA**	**30 DAA**	**35 DAA**	**40 DAA**	***F***	***P***
Fruits	Weight (g)*	487.33±26.59[f]	658.00±57.63[e]	703.33±47.43[d]	823.33±43.88[bc]	890.00±46.08[b]	1066.67±60.88[a]	15.89	<0.001
	Diameter (cm)	5.71±0.29[e]	7.45±0.47[d]	8.16±0.40[d]	10.92±0.41[c]	12.56±0.22[b]	13.15±0.29[a]	68.23	<0.001
	Seed nb/ fruit	168.87±10.22[f]	212.00±11.18[e]	244.87±11.43[d]	323.40±13.36[c]	365.33±10.82[b]	400.40±12.39[a]	157.77	<0.001
Seeds	Lengh (mm)	11.13±0.12[d]	11.85±0.11[c]	12.45±0.07[b]	12.43±0.10[b]	12.38±0.08[b]	12.75±0.10[a]	46.30	<0.001
	Width (mm)	5.77±0.05[d]	5.87±0.09[cd]	5.83±0.06[d]	6.01±0.05[bc]	6.17±0.05[ab]	6.31±0.07[a]	11.53	<0.001
	Thickness (mm)	0.39±0.019[f]	0.96±0.02[e]	1.23±0.02[d]	1.436±0.018[c]	1.60±0.03[b]	1.69±0.02[a]	802.33	<0.001
	W100 (g)	3.84±0.05[f]	4.52±0.10[e]	5.28±0.16[d]	6.65±0.15[c]	6.98±0.26[b]	7.76±0.24[a]	540.78	<0.001
	GnP (%)	41.41±3.15[f]	68.35±3.28[e]	76.09±3.79[d]	83.50±3.50[c]	88.89±2.57[bc]	92.92±2.20[a]	69.77	<0.001
	GMT (days)	7.45±0.19[a]	7.48±0.11[b]	6.85±0.13[c]	5.51±0.09[d]	4.98±0.08[e]	4.69±0.08[f]	189.36	<0.001
	GSI (Sd/day)	2.01±0.26[f]	3.17±0.24[e]	3.98±0.42[d]	5.35±0.45[c]	6.41±0.56[b]	7.08±0.70[a]	134.37	<0.001
Seedlings	EmP (%)*	31.33±2.02[d]	55.66±4.39[c]	61.67±5.40[c]	73.67±4.88[b]	80.67±3.58[ab]	86.00±3.50[a]	37.61	<0.001
	EMT (j)	10.84±0.18[a]	10.30±0.12[b]	10.10±0.12[b]	9.44±0.09[c]	9.11±0.08[d]	8.11±0.09[e]	94.24	<0.001
	ESI (Gr/j)	0.74±0.05[e]	1.38±0.13[d]	1.63±0.16[c]	2.03±0.14[b]	2.25±0.14[b]	2.72±0.22[a]	66.14	<0.001
	SSL (cm)	7.91±0.16[d]	8.31±0.17[d]	8.73±0.17[c]	9.49±0.18[b]	9.97±0.21[a]	10.30±0.18[a]	43.69	<0.001
	LeL (cm)	4.43±0.06[e]	4.71±0.05[d]	4.98±0.05[c]	5.05±0.05[c]	5.28±0.06[b]	5.85±0.06[a]	82.32	<0.001
	LeW (cm)	4.41±0.05[e]	4.78±0.06[d]	5.06±0.06[c]	5.12±0.05[c]	5.43±0.06[b]	5.66±0.06[a]	68.93	<0.001
	FSW (g)	2.14±0.07[e]	2.96±0.08[d]	3.30±0.09[c]	3.57±0.11[b]	3.93±0.12[a]	4.05±0.11[a]	67.221	<0.001
	DSW (g)	0.23±0.005[e]	0.25±0.005[d]	0.28±0.004[c]	0.31±0.005[b]	0.31±0.006[b]	0.35±0.007[a]	83.54	<0.001

W100: weight of 100 dried seeds, GnP: germination percentage, GMT: germination mean time et GSI: germination speed index, EmP: emergence percentage, EMT: emergence mean time, ESI: emergence speed index, SSL: seedling shoot length, LeL: leaf length, LeW: leaf wide, FSW: fresh seedling weight, DSW: dried seedling weight, Sd: seedlings and d: days, DAA: days after anthesis values with the same superscript letter are not significantly different from each over (ANOVA, P > 0.05)

3.1.1.5 Ash content

Seed ash content in *C. lanatus*, ranging from 3.655 to 3.475%, did not vary significantly with harvest time. All fruit harvest times produced the same ash content in this *C. lanatus* cultivar.

3.1.1.6 Total phenolic compounds content

C. lanatus seed total phenolic compound content increased (from 0.081 mg/100g DM) after 15 DAA to reach its optimum (0.097 mg/100g DM) at 25 DAA and stabilized until 35 DAA, after which it fell again up to 40 DAA (Fig. 4). During fruit growth, phenolic compound content increases to reach its optimum around the 25th DAA, stabilizes until about the 35th DAA and then falls again until 40 DAA.

3.1.2 Impact of fruit harvest time on *Citrullus lanatus* seed agronomic qualities

Table 2 contains values of *C. lanatus* fruits, seeds and seedling parameters following fruit harvest time.

3.1.2.1 Incidence on fruits parameters

Delaying harvest (from 15 to 40 DAA) increased fruit weight (from 487.33 to 1066.67 g), diameter (from 5.71 to 13.15 cm) and seed content (from 168.87 to 400.40 seeds/fruit). The largest, heaviest fruits containing more seeds must be harvested late (40th DAA).

3.1.2.2 Effect on seeds parameters

Extending harvest time (from 15 to 40 DAA) enabled seeds to grow in length (from 11.13 to 12.75 mm), width (from 5.77 to 6.31 mm) and thickness (from 0.39 to 1.69 mm), while increasing their 100-seed weight (from 3.84 to 6.65 g). Similarly, the germination test revealed an increase in germination percentage (from 41.41 to 88.89%) and speed (from 2.01 to 6.41 seeds/day) and a reduction in mean germination time (from 7.45 to 4.98 days) with delay (from 15 to 40 DAA).

Late harvesting of the berries (40 DAA) produces the largest (long, wide and thick) and heaviest seeds, which also express high viability.

3.1.2.3 Impact on seedling vigour

Delaying harvest (from 15 to 40 DAA) of *C. lanatus* fruit increased seedlings percentage (from 31.33 to 86%) and emergence speed (from 0.74 to 2.72 seedlings/day), while shortening their mean emergence time (from 10.84 to 8.11 days). Similarly, extending harvesting time boosted seedling vigor by increasing shoot length (from 7.91 to 10.30 cm), leaf size (from 4.43 to 5.85 cm long and from 4.41 to 5.66 cm wide) as well as fresh (from 2.14 to 4.05 g) and dry (from 0.23 to 0.35 g) weight.

Overall, seeds from heavy, late-harvested fruit (at 40 DAA) produced the most vigorous seedling resulting in rapid emergence of the largest number of large, heavy, broad-leafed seedlings.

4. DISCUSSION

Improving nutritional, agronomic and economic qualities is linked, for any plant useful to man, above all, to their harvesting at optimum maturity during fruit development [9]. So we studied effect of harvesting time on the nutritional and agronomic qualities of the oilseed cultivar wlêwlê of C. lanatus. Our results showed that harvest time strongly affected fruit weight and seed quality, both for food, biochemical and agronomic use, through viability and vigour of seedlings produced.

Delaying fruit harvest (from 15 to 40 DAA) increased fruit weight and seed dry matter content through lipid (54%), proteins (30.50%), fibers (1.48%), flavonoids and vitamin C levels, which were optimal around the 30 and 35th DAA, while reducing their moisture content and anti-nutritional factors i.e. tannins. These optimum levels, ranging respectively from 48.66% to 66.60% for lipids, 27.12 to 32.37% for proteins and 1.00 to 2.00% found by Loukou et al. [6] during physico-chemical characterization of the same cultivar, confirm morphological maturity of *C. lanatus* seeds harvested around the 30th and 35th DAA. Therefore, this enhancement in seed biochemical quality with a later harvest could also be explained by the completion of biosynthetic processes for the main constituents, namely carbohydrates, proteins and lipids [30]. Indeed, the seeds increase in total phenolic compound content can be explained by their ripening. Indeed, [31] also reported that polyphenol content increases during fruit ripening, reaching maximum values. According to Atouati et al. [32] secondary metabolites improve oil stability and organoleptic characteristics, which improves fruit quality and/or seeds them produced. Ghanmi et al. [33] Already reported high yield, biochemical composition and bioactivity of essential oils of white mugwort (*Artemisia herba-alba*), as well as [34], in protein content of young cowpea leaves. Indeed tannins and flavonoid involvement in auto-oxidation and photo-oxidation mechanisms could explain their lower content in seeds of late harvested seed of *C. lanatus* wlêwlê cultivar. Similarly, [35] and [36] showed that early-harvested fruit (olives) produced greenish-white, very fruity oil with a low acidity level, and therefore very susceptible to oxidation in presence of light because of its very high chlorophyll content. In addition, these scientists noted that delaying harvesting improves yield and oil quality through increased acidity and a straw-yellow color that is generally less fruity. They explain this oil quality improvement by their low flavonoid and chlorophyll content, both involved in auto-oxidation and photo-oxidation mechanisms and tend to decrease during fruit ripening. Harvested between 30 and 35 DAA, *C. lanatus* wlêwlê cultivar fruits could provide an ideal source of dietary nutrients or perfect blend of energy and proteins required to reduce tiredness, and help muscle repair and recovery during the working day, especially after physical activity [37,38]. Furthermore, for elderly people, an increase in protein intake through *C. lanatus* dishes could help maintaining muscle strength and prevent physical deterioration [39]. However, seed ash content was not affected (3.00 and 3.65%) by delayed harvesting. These results confirm those of Enzonga-Yoca et al. [40] on freeze-dried milk from *Citrullus lanatus* and *Cucumeropsis mannii* with similar values (3.63% and 3.93%).

If delaying fruit harvesting improved earlier (around the 30th DAA) seed nutritional quality, its agronomic characteristics were improved by later harvest (around the 40th DAA). Consequently, *C. lanatus* seeds showed a lower moisture content through their powder when late harvested (at the 40th DAA), possibly due to their dehydration during formation. We Yao et al. [8] observed similar dehydration with the same variety seeds. So powder moisture reduction was due not only to drying but also to the ripening process. According to Hong et al. [41], seed dehydration is part of their maturation process. Moreover, their findings on seed viability are further confirmation of this maturation with dehydration. According to Sanogo et al. [42], this seed moisture content reduction, over and above their powder content, is also an advantage for storage**.** Agronomically, precocious seeds (20 DAA) showed, at least, viability. This relatively high viability (67.75%) indicates that physiological maturity of the first seeds began before 20 DAA. In addition, delaying harvest from 20 to 40 days after anthesis (DAA) significantly increased fruit weight and seed content. As a result, fruits late harvested at 40 DAA were the heaviest and contained more seeds than those harvested sooner at 35 DAA followed respectively by 30, 25 and 20 DAA. We also [17] reported an increase in fruit size and seed number following delaying harvest (from 30 to 50 DAA) in both oleaginous cultiavrs of *Lagenaria siceraria*. Delaying harvest time probably allowed remaining immature seeds to achieve their physiological maturation [9]. Indeed, seeds later harvested (40 DAA) certainly had more time to accumulate their nutrient reserves and reach a high physiological maturity in fruits before harvesting. According to Ambika et al. [43], the heavier the fruit, the more storage of nutrients devoted to the successful growth of its seeds. Our results also showed significantly improved in *C. lantus* seed viability through germination percentage (from 69.75 to 89.50%) when delaying harvest (from 20 to 40 DAA). [9] Reported similar seeds viability (from 75 to 100 %) in watermelon (*Citrullus lanatus*) with delaying harvest time (from 28 to 49 DAA). According to Valantin et al. [44], seeds from the heavier fruits are not only more numerous but also accumulate enough nutrients to better germinate. In addition, fruits harvested at 40 JAF provided more viable.

5. CONCLUSION

This study showed that both biochemical and agronomic parameters of *C. lanatus* cultivar wlêwlê seeds are strongly influenced by their fruits harvest time. Biochemically, delayed harvesting improves seed nutritional quality through an increase in protein, lipid, fibre, vitamin C and phenolic compound contents, and a reduction in tannin as an anti-nutritional factor, while seeds dehydrate considerably to reach their optimal levels around 35th DAA. Delaying the harvest also improves seed agronomic performance by increasing viability and seedling vigour at the 40th DAA. Therefore, this cultivar fruits should be harvested early at 35 DAA for nutritional purposes and later at 40 DAA for use as seeds for new plantings.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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