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Predicting the Longevity of Sesame Seeds under Short-Term Containerized Storage with Charcoal Desiccant

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Authors' contributions

This work was carried out in collaboration between all authors. Authors KOO and OKR designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author SEA co-ordinated the laboaratory work. Authors CCN, OAD and JAA participated in designing the experiment and writing the protocol. All authors also read and approved the final manuscript.

Research Article

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ABSTRACT

Seeds are characterized by rapid deterioration during storage under humid tropical conditions of high air temperature and relative humidity. Physiological changes that occur in seeds during storage are manifested as reduction in seedling vigor index, number of germination, percentage germination, speed of germination and rate of germination among others. This study aimed at prolonging the longevity of sesame seed through containerized storage with charcoal desiccant. Forty grams of sesame seeds was stored with varying amount of charcoal desiccant (0, 40, 80, 120, 160 and 200 g). The containerized seeds were then placed in a wooden cabinet with average ambient conditions of 29.8ºC and 80% relative humidity, and stored for 12weeks. Samples were taken from storage at interval of two weeks and tested for seed viability and seedling vigor. Analysis of variance (ANOVA) was carried out on the data collected and treatment means were separated using Duncan's Multiple Range Test (DMRT). Serial germination data were also subjected to probit analysis

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in order to model sesame seed deterioration in storage. ANOVA results show that charcoal treatments were highly significant ($P \le 0.01$) on all the seed viability and seedling vigour parameters evaluated. Storage time was also highly significant on all the parameters. However, interaction between seed treatment and storage time was not significant ($P \ge 0.01$) on seed germination and seedling vigour index. There were also statistical differences among the charcoal treatments and among the storage periods. Probit results indicate that seed preservation was optimal in seed treated with 200 g charcoal with seed half life (P_{50}) of 13.19 weeks, and lowest seed deterioration rate ($1/\sigma$) of 0.1559. It is recommended that 200 g or more of dry charcoal should be adopted for short-term and medium- term sesame seed treatment as it effectively maintained seed viability and seedling vigour during storage as compared to other treatments.

Keywords: Seed treatment; seed storage; seed viability; seedling vigour; seed deterioration.

1. INTRODUCTION

Seed deterioration starts immediately after a crop has attained the physiological maturity stage. In a crop seed like sesame (*Sesamum indicum L.*) deterioration is even faster immediately after harvest from the field; this is owing to its high oil content and fast cellular respiration occurring in the seed [1]. Several methods are being adopted therefore to encourage crop/seed shelf (storage) life while preserving it; and these may include: seed treatment with suitable chemicals or plant products, as well as seed storage in safe containers [2]. Roberts [3] reported that seed deterioration during storage was due to the damage in cell membrane and other chemical changes in the seed system such as the protein and nucleic acid accumulation. Such degenerative changes result in complete disorganization of membranes and cell organelles and ultimately causing death of the seed and loss of viability. Villiers [4] opined that the most common and consistent ultra-structural changes in all the cell organelles was the loss in integrity of membranes, which invariably leads to increased seed deterioration especially during storage.

The storability of seeds is also influenced by the type of packaging material. Seeds stored in moisture-proved sealed containers provide suitable environment for storage, offer protection against contamination and also acts as a barrier against the escape of seed treatment chemicals than in moisture pervious containers [5]. Miyagi [6] dried seeds of onion, carrot, cabbage, cucumber and tomato in desiccators and stored in moisture vapour-proof resistant and impervious containers. Higher viability and vigour was retained for longer periods in moisture-proof containers followed by moisture resistant and impervious containers, respectively.

In the tropics where the temperature can be as high as 33ºC and relative humidity of about 80%, seeds deteriorate rapidly [7]. Harrington [8] reported that for every one percent moisture decline and for each 5ºC decrease in temperature the storage period will be doubled. In open and pervious container, seed moisture content is determined by RH of the surrounding atmosphere and temperature of the storage environment. Robert [9] also opined that seed stored in ambient conditions loose their viability and vigour very fast due to change in environmental conditions.

Seeds begin to deteriorate as soon as they are harvested or collected. Depending on ambient temperature and humidity, there is a risk that they will be dead by the time they are needed for planting Harrington [10]. If more than 50% of the seeds have already died, potentially important characteristics will have been lost. Harrington [10] spelt-out four conditions for a particular seed lot/seed collection to remain alive and therefore, usable.

The most important factor, and probably the easiest to control, is seed moisture content. Correct drying and packaging can make the difference between seeds surviving for a few months at best to being a high quality resource available for use for many years, possibly decades, into the future.

The preservation of orthodox seeds by cold storage helps in sustaining seed viability; but the problem of high cost of electricity hampers this process because it raises the cost of seed preservation. Harrington [11] suggested that within the normal range of moisture and temperature for stored seed, each 1% reduction in seed moisture content or each 5ºC reduction in temperature doubles storage life of the stored seed. Since sesame is a small flat seed, it is difficult to move much air through it in a storage bin. Therefore, the seeds need to be harvested as dry as possible and stored at 6% moisture or less. If the seed is too moist, it can quickly heat up and become rancid [1]. Environmental conditions which are safe for seed storage from harvest to planting are not necessarily safe for longer periods. Controlled seed storage is thus very essential especially in tropical and subtropical conditions in order to maintain seed viability and seedling vigour for longer periods [5].

Charcoal and other inexpensive potential desiccants have the capacity to dry seeds when they themselves have been dried beforehand (this creates the water potential difference between the desiccant and the seeds to be dried which drives the drying process). Some traditional seed storage methods suggest placing a layer of charcoal on top of seeds before sealing them for storage. This technique may help to deter insects. However, dried charcoal and other desiccants such as dried rice can also be used to dry seeds before storage. Charcoal and seeds such as rice or maize are readily available, inexpensive potential desiccants that can be found in rural areas throughout the world. The desiccant must be dry to start with, otherwise it will not be able to absorb much moisture, and the seeds will not dry properly. Being black in colour, charcoal has the potential to absorb solar heat during the day thus causing it to dry below ambient humidity levels. Also, charcoal exposed to direct sun for about 5 hours will reach a very low moisture level and will have a lot of drying potential.

The major objective of this study is to estimate sesame seed longevity using improvised containerized dry storage at ambient conditions of the humid tropical environment.
The specific objectives are

1. To evaluate the effectiveness of containerized seed storage system.
2. To evaluate the efficacy of dry charcoal as seed storage desiccant.
3. To monitor and predict the seed viability and seedling vigour perfornances of sesame seed during low-tech. storage at ambient seed storage condition.

2. MATERIALS AND METHODS

2.1 Seed

The crop seed used for this work was sesame (*Sesamun indicum*) INCRIBEN-01. The seed was collected from the National Center for Genetic Resources and Biotechnology (NACGRAB), Ibadan South west Nigeria.

2.2 Initial Seed Quality Evaluation

Petri dishes were dried for 4 hours and put in the desiccators for 1 hour in order to attain constant weight. Wet Filter paper was placed in the Petri dishes and 50 seeds of sesame crop were counted and sowed in triplicates. Seeds were then evaluated for percent seed germination, seedling length, seedling vigour index, speed of germination and rate of germination as follow:

$$Percent\ Seed\ Germination\ = no\ of\ seed\ germinated\ /\ no\ of\ seed\ sowed\ X\ 100$$

$$Seedling\ vigour\ index\ (SVI) = percent\ seed\ germination\ X\ seedling\ length.$$

$$Speed\ of\ germination\ (SOG) = \frac{no\ of\ seed\ at\ first\ count}{day\ of\ first\ count} + \frac{no\ of\ seed\ at\ second\ count}{day\ of\ second\ count} - - - - - - - - - + \frac{no\ of\ seed\ at\ final\ count}{day\ of\ final\ count}$$ [12]

Rate of germination = $1/t_n$ (ΣG_n) [13].

where t_n = total time taken
$\Sigma\ G_n$ = cumulative germination count.

The initial seed moisture content of the seed lot was determined by the modification of the gravimetric (forced air) oven method (ISTA, 1985[14]); using the formula:

% Seed MC (fw. b) = (M2-M3)/(M2-M1)X100

Where, M1 = weight of Petri dish, M2 = weight of Petri dish plus fresh seeds, M3 = weight of petri dish plus dried seeds. The seed moisture content was determined in triplicates, using 5 g of seed per replicate.

2.3 Seed Treatment, Packaging and Storage

The surface area of local charcoal was increased by breaking it into smaller pieces, after which it was oven-dried for 4 hours. The dry sample was removed afterwards and kept in desiccators for another 1hr to cool and return to constant weight. At this time the moisture content of dried charcoal (i.e before subsequent use) was 2%. Forty (40) grammes of sesame seed was also weighed and packed into six separate 2mm net bags which were suspended in plastic containers with varying amounts of charcoal desiccants (0, 40, 80, 120, 160 and, 200 g). The seed treatments are as follow:

40 g Seed: 0 g Charcoal (1:0)
40 g Seed: 40 g Charcoal (1:1)
40 g Seed: 80 g Charcoal (1:2)
40 g Seed: 120 g Charcoal (1:3)
40 g Seed: 160 g Charcoal (1:4)
40 g Seed: 200 g Charcoal (1:5)

Treated and containerized seeds were later stored in semi-sealed wooden cabinets for a period of 12 weeks, during when seed viability, seedling vigour and seed moisture content of sesame were evaluated. The containerized storage environment and the cabinet environment were monitored with thermohygrometers.

2.4 Seed Viability and Seedling Vigour Evaluation

This was carried out as in the initial seed quality evaluation.

2.5 Statistical Analyses

Data collected from this experiment were analyzed using SAS (Statistical Analysis System) version 9.0 SAS [15]. Analysis of variance (ANOVA) was carried out; (where storage time and seed treatment are factors), in order to test if the factors were significant on the parameters evaluated. Means from AVONA were separated using Duncan's Multiple Range Test (DMRT), to be able to separate treatment means that are significant. Probit analysis was also carried out on the serial germination data; to model seed deterioration in storage and predict seed survival. Parameters estimated are: Seed half-life (P_{50}), Probit value of the initial seed quality (Ki), Rate of seed deterioration (1/δ) and Standard deviation of time to seed death (δ).

3. RESULTS AND DISCUSSION

3.1 Effect of Seed Treatment and Storage Period on Seed Viability and Seedling Vigour of Stored Sesame Seeds

Means square from analysis of variance of seed viability and seedling vigour variables are presented in Table 1. Treatment and storage time are highly significant ($P \le .01$) on all the parameters (Nogerm-number of germination, Pergerm-percent germinated, SVI-seedling vigor index, ROG-rate of germination, SOG-speed of germination) evaluated. The interaction effect of treatment and storage time was not however significant ($P \ge .05$) on number of germinated seeds, percent germination and seedling vigour index, but highly significant on speed of germination and rate of germination. This is in line with the works of Nagaveni [5], Ejeromedoghene [16] and Akinkuotu [17], who reported that interaction between storage time and seed treatment were highly significant on seed viability and seedling vigour attributes.

Table 1. Means square from analysis of variance of charcoal treated sesame seeds stored for 12 weeks under ambient storage condition

Variables SOV	Df	No germ	% Germ	SVI	SOG	ROG
Trt	5	152.34**	614.66**	16904.50**	1.39**	1.38**
Time	4	1630.71**	6462.11**	58038.31**	40.07**	20.80**
Trt*Time	20	14.47	57.52	4625.52	0.62**	0.87**
Error	60	11.41	46.53	2467.46	0.27	0.39
Total	89					

**: significant at 5% level of probability; **: significant at 1% level of probability; Df: Degree of freedom; SOV: sources of variation; No Germ: number of germinated seed; % Germ: percentage germination; SOG: speed of germination; ROG: rate of germination; SVI: seedling vigour index; Trt: treatment.*

3.2 Mean Performances of Seed Viability and Seedling Vigour Variables of Stored Sesame Seeds under Six Dry Charcoal Treatments

Means of seed viability and seedling vigour variables for six charcoal desiccant treatments of sesame seeds stored for 12 weeks under ambient condition are presented in Table 2. There were no significant differences in all the treatments (0, 40, 80, 120 and 160 g) for all the variables evaluated except in 200 g; which had highest significant performances for the seed viability and seedling vigour parameters evaluated. This is similar to the work of Usha et al. [18], Akinkuotu [16], Ejeromedoghene [17] and Singh and Dadlani [19], who recorded significantly higher seed germination for stored sesame and soyabean seeds under low-cost storage conditions.

Means of seed viability and seedling vigor variables of sesame seed stored for 12 weeks are presented in Table 3. The results show that differences were noticed across the storage periods (3, 6, 8, 10 and 12 weeks) for all the parameters evaluated except in a few situations. Seedling vigour index was not different at 10 weeks (142.85c) and 12 weeks (128.90c). Also, speed of Germination (SOG) was not different at 3 weeks (2.99b) and 8 weeks (3.04b). This was also the same at 6 weeks and 12 weeks for rate of germination (ROG), in which results were not different. This result is in contrast with what Gupta et al. [20] reported on similar works.

Table 2. Means of viability and vigour variables for six charcoal desiccant treatment of sesame seeds stored for 12 weeks under ambient condition

Treatments(grammes)	No Germ	% Germ	SVI	SOG	ROG
0	32.80b	65.47b	189.07b	3.27b	4.31b
40	30.40b	60.80b	181.41b	3.16b	4.23b
80	31.13b	62.00b	197.27b	3.27b	4.07b
120	32.87b	65.73b	165.10b	3.03b	4.23b
160	30.47b	60.93b	176.87b	3.50b	3.98b
200	38.87a	77.73a	259.71a	3.89a	4.85a

Means with the same letter are not significantly different; No Germ: number of germinated seed; % Germ: percentage germination; ROG: rate of germination; SVI: seedling vigour index; SOG: speed of germination.

Table 3. Means of viability and vigor variables of sesame seeds stored for 12 weeks under ambient storage condition

Time (weeks)	No Germ	% Germ	SVI	SOG	ROG
3	42.94a	85.56a	256.86a	2.99b	6.13a
8	39.06b	78.11b	237.44ab	3.04b	5.58b
6	35.67c	71.33c	208.48b	5.25a	3.10d
10	26.39d	52.78d	142.85c	2.62b	3.77c
12	19.72e	39.44e	128.90c	2.82b	2.82d

Means with the same letter are not significantly different; No Germ: Number of Germinated seed; %Germ: Percentage Germination; SVI: seedling vigour index; SOG: speed of germination, ROG: rate of germination.

Table 4 shows means of viability and vigour variables evaluated for sesame seeds under six dry-charcoal treatments during 12 weeks storage period. For the untreated control (O g charcoal), mean seed viability and seedling vigour values were statistically different across the storage periods; with significantly highest number of germination (49.00a), germination percent (89.33a) and rate of germination (6.28a) recorded at 3 weeks. For charcoal treatment at 40 g, SVI and ROG did not show any difference at 10 and 12 weeks; while SVI performance for this treatment was also significantly highest (278.45a) at 3 weeks, but lowest (95.09c) at 12 weeks of storage. Mean performances of 200 g dry charcoal treatment for all the seed viability and seedling vigour variables were significantly different across the storage periods. However, SVI and ROG were significantly highest (300.53a and 6.48a respectively) at 8 weeks under 200 g treatment. Though there was disparity in results of mean seed viability and seedling vigour observed across charcoal treatments and seed storage time, but the significantly highest seedling vigour performance (SVI) for treatment X time interaction was obtained with 200 g charcoal treatment and at 8 weeks of seed storage (300.53). These results indicate that the more the quantity of dried charcoal used for the sesame seed storage the more conducive the storage environment; thus prolonging and preserving the agronomic qualities of the crop seed. Similar results were also reported by Oyekale et al. [1], Ejeromedoghene [16] and Akinkuotu [17], who argued that seed viability and seedling vigour of seeds in storage are maintained with moisture manipulation of the storage environment.

Table 4. Means of viability and vigour variables evaluated for sesame seeds in containerized charcoal treatment under ambient seed storage condition

Variables Trt	Time(wks)	No Germ	%germ	SVI	ROG	SOG
0	3	45.00a	89.33a	268.73a	6.28a	2.59b
0	6	35.00b	70.00b	221.87a	3.27b	5.95a
0	8	38.00ab	76.00ab	236.61a	5.43a	3.13b
0	10	25.33c	50.67c	110.35b	3.62b	2.18b
0	12	20.67c	41.33c	107.80b	2.95b	2.50b
40	3	38.33a	76.67a	278.45a	6.14a	3.09b
40	6	32.66a	65.33a	196.59b	3.47cb	4.67a
40	8	36.00a	72.00a	212.83b	5.14b	2.94b
40	10	26.00b	52.00b	124.08c	3.71c	2.57b
40	12	19.00c	38.00c	95.09c	2.71d	2.52b
80	3	41.00a	80.67a	285.67a	5.57a	3.50b
80	6	36.33a	72.67a	263.03a	3.59b	5.19a
80	8	38.67a	77.33a	220.37ab	5.51a	2.84bc
80	10	23.00b	46.00b	130.00bc	3.29bc	2.35c
80	12	16.67c	33.33c	87.31c	2.38c	2.46c
120	3	42.67a	46.00a	239.49a	6.19a	3.35b
120	6	33.67bc	33.33bc	158.51ab	2.40c	4.81a
120	8	40.00ab	85.33ab	197.19a	5.71a	2.44bc
120	10	27.33cd	67.33cd	146.71ab	3.90b	2.67bc
120	12	20.67d	80.00d	83.59b	2.95c	1.89c
160	3	45.00a	90.00a	217.00ab	6.52a	2.45b
160	6	33.67b	67.33b	179.00bc	2,87c	4.81a
160	8	36.33b	72.67b	257.08a	5.18b	3.55ab
160	10	20.67c	41.33c	128.24cd	2.95c	2.98b
160	12	16.67c	33.33c	103.05d	2.38c	3.72ab
200	3	45.67a	91.33a	251.99a	6.10a	2.75c
200	6	42.67a	85.33a	231.91a	3.00c	6.10a
200	8	45.33a	90.67a	300.53a	6.48a	3.37bc
200	10	36.00b	72.00b	217.75a	5.14b	2.97c
200	12	24.67c	49.33c	296.56a	3.52c	4.23b

Means with the same letter along the columns are not significantly different; Trt: charcoal treatments; No Germ: number of germinated seed; %Germ: percentage germination; SVI: seedling vigour index; SOG: speed of germination, ROG: rate of germination.

3.3 Estimates of Probit Viability

Results from assessment of probit longevity for sesame seed stored under various seed desiccant ratios are presented in Table 5. The parameters estimated were Ki (Probit value of initial seed viability), 1/σ (Measure of seed deterioration in storage), σ =Standard deviation of seed death in storage) and P5O (Seed half-life or measure of time to 50% seed viability in storage). The highest Ki value (2.09) was recorded in 200g treatment; while rate of seed deterioration (1/σ) was highest (-0.1852) in 160g treatment. Seed storage life (half-life) was however longest (13.19 weeks) longest in seeds treated with 200g dry charcoal. This result agrees with what Ejeromedoghene (2010), who evaluated and modeled the storability of soyabean seed using dried charcoal observed. In fact, the initial quality of the seed before storage as indicated by the Ki value is a pre-requisite for the seed storability.

Table 5. Estimates of probit longevity for sesame seed stored with dried charcoal at various seed desiccant ratios

Probit parameters Trts (grammes)	Intercept (Ki)	Slope (1/σ)	Sigma (σ)	Half-life (P5O)
0	1.69	-0.1588	6.30	10.66
40	1.14	-0.1095	9.14	10.45
80	1.57	-0.1559	6.41	10.04
120	1.47	-0.1317	7.59	11.14
160	1.77	-0.1852	5.40	9.58
200	2.09	- 0.1586	6.31	13.19

Trts = Charcoal treatments; Ki = Probit value of initial seed viability; I/σ =Measure of seed deterioration in storage; σ =Standard deviation of seed death in storage; P5O=Seed half-life or measure of time to 50% seed viability in storage.

3.4 Seed Moisture Trend in Stored Sesame Seed

Initial seed moisture content of the sesame seed at the point of storage was 12%; and this was the same for all seed samples shared into various charcoal treatment containers at the beginning of storage. Mean storage temperature in the wooden cabinet, where the seed storage arrangement was placed, was 28 ± 2ºC. In the charcoal treatment containers however, mean relative humidity throughout the 12 weeks storage period varied from 80-85% in untreated control to 50-75% in 200 g charcoal treatment container.

The seed moisture changes in stored sesame seeds under varying amounts of charcoal desiccant are presented in Fig. 1. At 3 weeks, 160 g charcoal treatment has the highest moisture percent (4.5%), followed by 40 g (4.3%), 80 g and 120 g (4%). The lowest moisture regime is however recorded for 200 g charcoal treatment (3%). At 6 weeks, the highest was observed in 80 g treatment (5.9%), followed by 120 g (4.5%), 40 g (4%), 0 g (3.1%), 200 g (3%) and 160 g (2.2%). At 8 weeks, 40 g charcoal treatment has the highest moisture regime (4.5%), with the lowest observed in the control treatment. At 10 weeks, moisture was highest in 200 g (3.9%) and lowest in 120 g (2.7%) charcoal treatment. Also at 12 weeks after storage, moisture was highest in 40 g (4.9%) and lowest in 120 g (2.9%). The moisture trend thus shows that sesame seeds stored with 200 g dry charcoal already had their moisture reduced to 3% by the end of first 3 weeks and this was maintained at around the same point even at 12 weeks. This of course would have been occasioned by the drier storage environment created by higher volume of the dried charcoal used (200 g). This result is in line with the work of Ejeromedoghene [16], who reported that seeds stored under higher seed : desiccant ratios had significantly reduced moisture content throughout storage period, and also had their viability and vigour better maintained than those stored with reduced quantity of charcoal desiccant. Therefore, the storage life of seeds stored under moisture-controlled environment is usually longer than seeds stored under ambient storage conditions; and seed deterioration is often faster in the later [21].

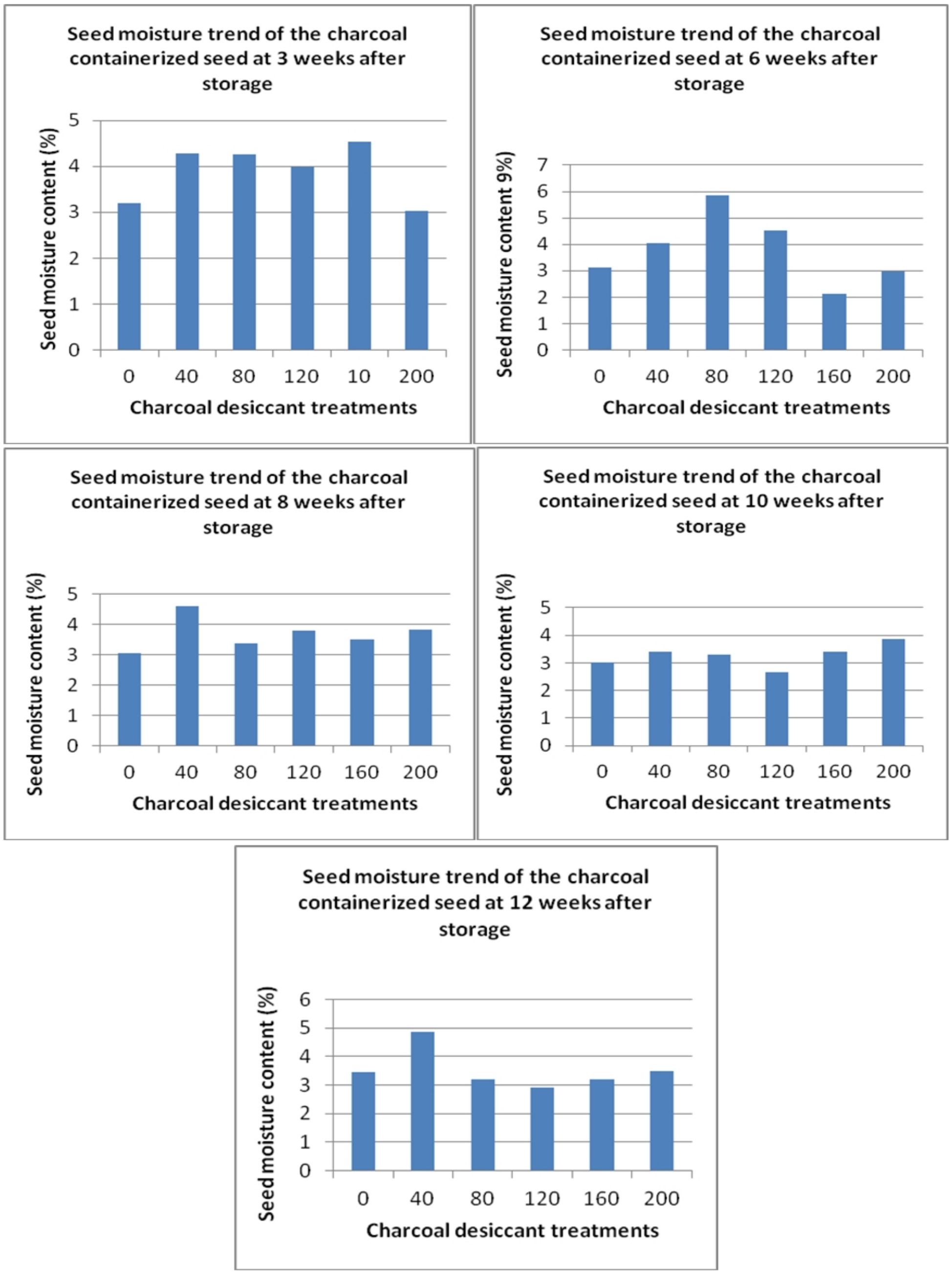

Fig. 1. Seed moisture trends of five charcoal desiccant treatments during 12 weeks of storage

4. CONCLUSION

Among all the charcoal desiccant treatments, 200 g significantly enhanced seed viability and seedling vigour throughout the 12-week storage period. It may therefore be concluded that sesame seed stored with high quantity of dry charcoal (200 g or more) can maintain seed quality for up to 13 x 2 weeks. Dry charcoal as a type of seed storage desiccant is a very effective tool in safe seed storage and should be adopted as a low-cost seed storage desiccant technology, especially for oil crops for short and medium term seed storage. However, in storing sesame seed consideration should be given to the initial quality of the variety in question; because better initial quality may likely guarantee longer storability and longevity of the seed.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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