RESEARCH | Egyptian Journal of Agricultural Research | Field Crops

Effect of pre- harvest field weathering on seed quality of soybean grown under irrigation in dry region

Yasmeen S. Abdelhamied[1*], *Abdelaziz A. Kandil*[1], *Ola Z. El-Badry*[1], *Moemen H. Taha*[1] *and Eman A. Ibrahim*[2]

Address:

[1] *Agronomy Department, Faculty of Agriculture, Cairo University, Giza, Egypt*

[2] *Seed Technology Research Department, Field Crops Institute, Agricultural Research Centre, Giza, Egypt*

*Corresponding author: **Yasmeen S. Abdelhamied** email: yasmeensinousy@agr.cu.edu.eg

Received: 25-07-2023 **; Accepted:** 28-06-2024 **; Published:** 03-07-2024 **DOI**: 10.21608/ejar.2024.225129.1419

Abstract

The experiment was sown in 2018 and 2019 summer seasons at Agric. Exp. and Res. St., at Giza, Egypt to study the effect of field weathering on seed quality of soybean. Soybean Giza 111 cv. was harvested in physiological maturity (PM), 7, 14 and 21 days after PM. Harvesting at 7 days after PM produced greatest normal and green seed % but delaying harvesting after that increased defective seed%, EC value and decreased seed weight. Highest seed germination % and normal seedling%, longest and heaviest seedling were recorded from the seed harvested at PM which showed highest oil and protein content and highest values of seedling vigor index. The variation in the period from flowering to threshing and the day temperature during the period were participated with a great percentage of variation in the most of these traits.

Keywords: Soybean, field weathering, seed quality.

INTRODUCTION

Soybean [*Glycine max* (L.) Merr.] ranked first among oil seed crops globally on basis of its cultivated area (126.9 mil. ha) and seed production (353.4 mil. ton) according to (FAO, 2020). The main producing countries of soybean are Argentina, Brazil, USA, China and India; thus, it is grown in wide geographical zones vary in their environment conditions during growing season. In context, > 70 % of soybean area in the world grown as a rain fed crop, the climate of such raining locations during the growing season of soybean may be cause seed deterioration when such weather conditions prevailed at pre- or post-maturity and harvesting. Katembo, *et al*. (2018). Stated that harvesting soybean when 65% of pods had ripened showed highest moisture content and highest green seed percentage. On other hand, delay harvesting 28 days after this stage decreased moisture content up to suitable level for harvesting with zero green seed, but increased cracked seed and germination percentage with different values for the four studied cultivars. Dornbos (2020). Stated that weather factors such as high air temperature and high relative humidity during maturation of soybean seed caused seed deterioration which makes it is difficult to produce high quality seed in tropics and sub- tropics. At physiological maturity, soybean seed reach the highest potential of viability and vigor, but the seed at this stage has high moisture content, make the commercial harvesting with machines become unwise. For that, there is period (few days to few weeks) between physiological maturity and harvest maturity (13-14% seed moisture content). Unfortunately, seed deterioration usually happened during this period in the hot and humid climates (Delouche, 2021). Raj *et al*. (2021) stated that high air temperature and low relative humidity during soybean harvesting reduced seed quality through the physical and physiological attributes.

The deterioration in soybean seed was attributed with decreased in oil and protein and increase in carbohydrate contents (Nagar *et al*, 2018), the deterioration could be +appened due to the damage occurred to seed coat, easy penetration of disease pathogens which produce materials cause cell membrane damage (Ali, *et al*., 2019). The maximum potential of germination of soybean seed was shown at physiological maturity (Staniak *et al*., 2023 and Poudel, *et al*., 2024) however, it could not harvest at this stage due to high moisture content >)30 %) in the seed. However, delay harvesting of soybeans after physiological maturity not only affect seed viability and vigor but also may cause mechanical damages during harvesting and processing which may be increase disease infection (Guleria, *et al*., 2018; Chhabr and Singh, 2019). In context, Pinheiro *et al.* (2021) stated that adverse weather after flowering of soybean induce early mature seed, yield reduction and low seed quality. Furthermore Ali *et al.* (2019) reported the miss-shape and off-color seed were increased when the seed remained on the mother plant after physiological maturity of pulse crops. Pinheiro *et al.* (2023) stated that the reduction in physiological seed quality traits starts just after the seed reaches to physiological maturity under tropical environments. This reduction increased as plants exposed to field weathering from 1 to 4 weeks either for the susceptible or for the tolerant varieties, but with higher reduction rate in susceptible one. Pinheiro *et al.* (2021) stated that wrinkles seed coat due weathering was related to reduction in physiological parameters of soybean, in context, Fialho *et al.* (2023) stated that soybean varieties were grown under pivot irrigation system at R8 growth stage and found that their seed deterioration rate was different, the cultivar had highest lignin content in the seed coat has the lowest percentage of damage and highest physiological quality. High relative humidity and air temperature during seed maturation causes less germination ability and increase abnormal seedling due to the damage occurred to the seed cellular membrane which increase its permeability and the EC values of seed leachates (Nagar *et al.*, 2018). Pre- harvest rainfall reduced seed germination and its vigor with different figures among the tested varieties, this was attributed with wrinkling in seed coat (Pinheiro *et al.*, 2021).

Soybean seeded with low quality seed the farmers should use higher seeding rate than the recommended to obtain the desired plant density in the field, this means more expense. For that high quality seed is needed for the soybean farmers to get the recommended plant population density in the field aiming to obtain high yield without additional costs. The previous studies cleared that the hot and humid weather conditions can causes some kind of deterioration to soybean seed. In Egypt, where this study was carried out, its climate is very dry (precipitations rate falls on the North coast area is about 100-150 mm) during winter season (Nov-Feb.) while, soybean is grown with full irrigation during summer season (May- Sept.). For that this investigation aimed to study the effect of field weathering after physiological maturity and before harvesting under dry conditions in Egypt on physical seed traits, seed viability and seed vigor attributes and their relation to seed constituents and the prevailed climate factors under dry conditions in Egypt.

MATERIALS AND METHODS

Growing conditions:

Two field experiments were carried out during 2018 and 2019 summer seasons at Agricultural and experiments Research Station, Faculty of Agriculture, Cairo University, at Giza, Egypt (30.00N, 31.3E and elevation of 24 m). Soybean variety Giza 111 was sown on May 30 and June 23 in the two successive seasons, respectively. It is grown in four strips, each strip contains 30 ridges 60-cm apart, 5 meter long, seed were hand drilled at seeding rate of 20 gm. / row -5 m long (70 kg /ha.) in a pre-irrigated soil and when soil contains enough moisture to seed germination. The soil of the experimental site was clay loam in texture, has 42.3% and 16.3% moisture at field capacity and wilting point, respectively, and contains 9.5 ppm available N, 3.0 ppm available P and 580 ppm available K, with pH of 7.7 and EC 1.3 ds/m (1:2.25) as an average of both seasons. Calcium super phosphate (15.5% P_2O_5) was added before ridging at 30 kg P_2O_5 / faddan (one faddan = 4200 m^2 = 0.42 ha). Just before 1st and 2nd irrigation weed control was done by hand hoeing twice, two and four weeks after sowing. Nitrogen fertilizer (60 kg N / faddan) as ammonium nitrate (33% N) was added in two equal doses at 15 and 30 days after sowing.

COLLECTED DATA

Meteorological data:

Meteorological variables in the 2018 and 2019 growing seasons of soybean were obtained from Agro-meteorological Station at Giza, Egypt from May to November. The values of the variables during the period from flowering up to threshing the harvested soybean plants to obtain seed are tabulated in Table 2 and 3. Flowering date was recorded when 5 plants in 10 ridges of each strip shown the first flower, the physiological maturity date was recorded when one pod has reached to the maturity color on 5 plants in 10 ridges of each strip.

Treatments:

To study the effect of field weathering on seed quality we need seed lots produced from plants exposed to different periods of field weathering before harvesting, to achieves this the four strips were harvested on different dates as follows:

1- Harvesting at (R7) physiological maturity (HD_1).
2- Harvesting at 7 days after R7 (HD_2).
3- Harvesting at 14 days after R7 (HD_3).
4- Harvesting at 21 days after R7 (HD_4).

Table 1. Agenda of sowing, flowering, harvesting and threshing in 2018 and 2019 seasons.

Treatment	2018				2019			
	HD_1	HD_2	HD_3	HD_4	HD_1	HD_2	HD_3	HD_4
Sowing date (SD).	30/5/2018				23/6/2019			
Flowering date (FLD).	2/7/2018				23/7/2019			
Harvesting date (HD).	16/9	23/9	30/9	7/10	5/10	12/10	19/10	26/10
Threshing date (ThD).	23/9	28/9	3/10	9/10	15/10	19/10	25/10	30/10
Days from SD to FLD.	33				30			
Days from FLD to HD.	75	82	89	96	72	79	86	93
Days from HD to ThD.	7	5	3	2	10	7	6	4
Days from FLD to ThD.	82	87	92	98	82	86	92	97
Days from SD to HD.	108	115	122	129	102	109	116	133

Table 2. Average temperature, humidity and possible sunshine hours parameters during flowering to threshing date for each treatment in 2018 season.

Treatment	Temp.(C°)				Relative Humidity (%)			Possible sunshine hours (PSSH)
	Max.	Mini.	Avg.	Day time	Max.	Mini.	Avg.	
HD_1	36.20	24.20	30.20	33.50	80.69	30.85	55.77	12.42
HD_2	35.30	24.18	29.70	33.4	81.21	30.84	56.26	12.36
HD_3	36.80	24.20	29.92	32.90	83.15	30.62	56.88	12.33
HD_4	36.86	24.53	30.96	31.90	81.15	32.99	57.07	12.00

Table 3. Average temperature, humidity and possible sunshine hours parameters during flowering to threshing date for each treatment in 2019 season.

Treatment	Temp.(C°)				Relative Humidity (%)			Possible sunshine hours (PSSH)
	Max.	Mini.	Avg.	Day time	Max.	Mini.	Avg.	
HD_1	36.15	22.92	29.53	33.34	78.30	40.10	59.20	12.45
HD_2	35.72	22.76	29.24	32.86	78.98	30.41	54.69	12.34
HD_3	34.65	21.91	28.28	32.20	79.30	30.69	54.99	12.34
HD_4	34.37	21.76	28.06	31.80	79.50	31.63	55.56	12.00

At each harvesting date, a random sample of 10 plants from each strip were taken, the seed were hand separated and the moisture content of normal seed was measured using Delta-T Devices - Model HH2 - Moisture Meter.

Seed measurements:

After harvesting, plants of each strip left on the ground until the plants become dry and suitable for threshing manually (seed contains 14-15% moisture) where the pods and seed were separated manually, taking care to avoid loss any seed. The seed left to dry at room temperature, when the seed moisture content reached 8-10 %, then stored in textile bag until carry out the following measurement 6 month later for each treatment.

Physical seed characteristics:

Four seed samples (500 gram each) were randomly taken from the yield of each strip, the following traits were recorded:

1. Defective seed percentage (DS %), by weight: damaged, shriveled, infected, atrophic and misshaped seed.
2. Green seed percentage (GS %), by weight: the seed of green color (dark or light) were separated and weight, then calculated as percentage.
3. Normal seed percentage (NS %), by weight: the rest of 500 gm. seed sample was calculated as percentage.
4. Seed with cracked seed coat percentage (SCSC%): four replications of 100 normal seed for each were mixed with red powder in color, next day the seed were visually fixed, those with red cracks on seed coat were counted and calculated as percentage.
5.500- seed weigh–g (SW): as an average weight of four samples of 500 normal seed taken randomly from the yield of each treatment.

The rest of the normal seed were used for the following tests

Seed viability and vigor parameters:

Germination test was performed using the normal seed only, four replications of 25 soybean seed from each treatment were soaked in a 5% hydrogen peroxide for 3 minutes, then rinsed several times with distilled water before replaced and sown in sterilized sand in petri dishes 12.5cm diameter then placed in an incubator at

25±2°C.Total number of germinated seed were counted daily until the 7th day the recorded data at the 7th day were used to calculate the following traits:
1. Seed germination percentage (SG %): was calculated as described in the Rules for Testing Seed (Association of Official Seed Analyst (A.O.S.A) 1986).
2. Speed germination index (SGI): It was calculated as described in the Association of Official Seed Analysis (A.O.S.A, 1983) by following formula:
SGI= (No. of germinated seed/days of first count) + (……. /…….) + (No. of germinated seed/days of final count).
3-Percentage of normal seedling (NSL %): the seedling considered normal when it has all of the essential structures present for normal growth.
4. Percentage of abnormal seedling (ASL %): the seedling considered abnormal when it missing one or more of its essential seedling structures; this maybe the root, the shoot or the terminal bud.
5. Seedling length (SLL): average length (cm) of 10 seedlings.
6. Seedling dry weight (SLDW): average weight (g) of 10 seedlings.
7. Seed vigor index I (SVI-I) = Germination (%) x Seedling length (Root +Shoot)
8. Seed vigor index II (SVI-II) = Germination (%) x Seedling dry weight (Root +Shoot) According to Abdul-Baki and Anderson (1973).
9. Seed electrical conductivity (EC) by using electrical conductivity cell model 115 According to (ISTA, 1993), samples of 100 seed of each treatment in four replicates, 25 seed each were used, according to the procedures outlined by (ISTA, 1993). The seed were weighed and placed in Erlenmeyer flasks (250ml) containing 200 ml of deionized water and cover by aluminum foil. The flasks were then placed in an incubator chamber at 25° C for 24 hours. The conductivity of seed steep water was measured immediately after the removal of samples from the incubator with a pipette-type conductivity cell attached to a bulk conductivity meter. The seed conductivity values were expressed as uS / cm/g. Results put in the formula:
Conductivity (uS cm-1) / Seed sample weight (g) = uS / cm/g
The seed viability and vigor tests were carried out at Laboratory of Seed technology Research Department, Agriculture Research Center (ARC) at Giza, Egypt.

Seed constituents:
Four 100 gm. seed samples were randomly taken from the stored normal seed of each treatment for determination the following seed constituents:
1. Oil content (%) Crude oil content (%) was determined using Soxtherm apparatus (A.O.A.C., 2000).
2. Protein content (%): nitrogen content (%) was determined using kjeldatherm and vapadest50s apparatus (A.O. A.C., 1995), and then N content was multiplied by 6.25.
3. Total Carbohydrate (%): was determined according to Dubois *et al*. (1956)
4. Ash (%): was determined according to A.O.A.C. (1990).
5. Fiber (%): was determined according to A.O.A.C. (2005) Gaithersburg, Maryland, U.S.A.

Statistical analysis:
The following traits were statically analyzed using MSTAT-C v. 3.1., (1988). Least Significant Difference (LSD) was applied to compare mean values.
1. Results of the physical seed traits, seed viability, seed vigor and seed constituents parameters were statistically analyzed as completely randomized design.
2- Simple regression coefficient and coefficient of determination (R^2) between exposing period to field weathering, temperature and relative humidity as an independent factors and physical seed traits, seed constituents traits and seed viability and vigor traits as dependent factors.

RESULTS

Physical seed characteristics:
Result in Table 4 show the effect of harvesting date on physical seed traits, which were significantly affected by harvesting date in 2018 and 2019 seasons. The highest normal seed percentage and heaviest 500- seed weight was recorded when harvesting took place 7 days after physiological maturity in both seasons, which estimated by 84.25% and 72.13 gm.

Table 4. Effect of harvesting date on physical seed traits of soybean in 2018 and 2019 seasons.

Physical seed characteristics	2018 season				2019 season			
	HD_1	HD_2	HD_3	HD_4	HD_1	HD_2	HD_3	HD_4
Normal seed (%)	76.50 c	85.75 ^{a}	80.00 ^{b}	66.00 ^{d}	80.25 ^{b}	82.75 ^{a}	82.25 ^{a}	76.75 ^{c}
Defective seed (%)	23.50 ^{b}	14.25 ^{d}	20.00 ^{c}	34.00 ^{a}	19.75 ^{b}	17.00 ^{c}	17.75 ^{bc}	23.00 ^{a}
Green seed (%)	5.53 ^{a}	2.20 ^{b}	1.02 ^{c}	1.04 ^{c}	2.32 a	0.42 ^{b}	0.00 ^{b}	0.00 ^{b}
Seed of cracked seed coat (%)	8.50 ^{d}	11.75 ^{c}	14.50 ^{b}	16.50 ^{a}	4.50 ^{d}	13.50 ^{cb}	15.25 ^{b}	17.50 ^{a}
500- seed weight(g)	70.50 ^{ab}	72.25 ^{a}	66.75 ^{bc}	64.75 ^{c}	71.25 ^{a}	72.00 ^{a}	69.50 ^{b}	68.00 ^{b}
Seed moisture content at harvesting (%)	43.50 ^{a}	29.50 ^{b}	20.25 ^{c}	15.50 ^{d}	44.25 ^{a}	26.50 ^{b}	19.50 ^{c}	16.75 ^{d}
Seed electrical conductivity (uS / cm/g)	24.00 ^{c}	33.13 ^{b}	42.60 ^{a}	45.23^a	25.75 ^{c}	32.63 ^{b}	47.13 ^{a}	47.00 ^{a}

respectively, as an average of the two seasons. Early harvesting at physiological maturity decreased normal seed percentage by 3.78 percent points and 500 - seed weight by 1.25 gm as an average of the two seasons (Table 4). However, highest green seed percentage (3.96%) was observed for harvested soybean plants harvested at physiological maturity, thereafter it decreased to 1.31, 0.51 and 0.52% as an average of the two seasons, when harvesting delayed up to 7,14 and 21 days after physiological maturity, respectively (Table 4).

HD_1= Harvesting at (R7) physiological maturity, HD_2= Harvesting at 7 days after R7, HD_3 = Harvesting at 14 days after R7, HD_4= Harvesting at 21 days after R7
Means followed by the same letter (s) are not significantly different at 5% probability**.**

In context, as an average of the both seasons, the highest seed moisture content (43.88%) at harvesting was recorded for the seed harvested at physiological maturity, then it decreased to 28.00%, 19.88% and 16.13 % when harvesting delayed to 7, 14 and 21 days after physiological maturity, respectively (Table 4).
On the other hand, as an average of the two seasons, the defective seed changed from 21.62 % to 15.63%, 18.88% and 28.50% when harvesting done at physiological maturity, 7, 14 and 21 days after, respectively. On the same order, the seed with cracked seed coat increased from 6.50 %, to 12.63 %, 14.88% and 17.00% (Table 4).
On the other side, the electrical conductivity of seed leachates increased from 24.88 to 32.88, 44.87 and 46.12 uS / cm/g (mean of the both seasons) when harvesting date delayed from physiological maturity to 7, 14 and 21 days later, respectively.

Seed constituents:

Results in Table 5 indicated that all seed constituents were significantly affected by harvesting date in the 2018 and 2019 seasons, except fiber and moisture content in 2019 season. The highest seed oil content was found when plants harvested at physiological maturity in both seasons with an average of 21.43%. When harvesting delayed up to 7, 14 and 21 days after physiological maturity it decreased by 0.56, 1.41 and 2.99 percent point (mean of both seasons), respectively. Also, and on the same order, highest protein content (37.05%) was observed for the seed harvested at physiological maturity, then it decreased by 0.61, 2.10 and 2.85 percent point when seed harvested at 7, 14 and 21 days later on respectively, as an average of both seasons (Table 5). On the other hand, carbohydrate content increased by delaying harvesting, where the lowest value was 18.70 % for the seed harvested at physiological maturity, thereafter it increased by 1.57, 2.88 and 4.48 percent point as an average of the two seasons when harvesting was done at 7, 14 and 21 days after physiological harvesting, respectively (Table 5).

On the other side, ash content was decreased with delay harvesting but with relatively narrow range i.e., from 6.68% to 5.46% in 2018 and from 6.57% to 6.07% in 2019 season. Also, fiber and seed moisture content show similar trend with significant differences in 2018 season only where fiber content decreased from 12.93 % at physiological maturity to 11.19%, while moisture content increased from 4.00% to 4.50% when harvesting delay up to 21 days after physiological maturity (Table 5).

Table 5. Effect of harvesting date on soybean seed constituents in 2018 and 2019 seasons.

Seed constituents	2018 season				2019 season			
	HD_1	HD_2	HD_3	HD_4	HD_1	HD_2	HD_3	HD_4
Oil content (%).	20.32 ^{a}	19.34 ^{ab}	18.42 ^{b}	18.6 ^{b}	22.53 ^{a}	22.40 ^{ab}	21.63 ^{b}	18.23 ^{c}
Protein content (%).	38.80 ^{a}	38.73 ^{a}	37.50 ^{b}	36.80 ^{c}	35.30 ^{a}	34.15 ^{b}	32.4 ^{c}	31.60 ^{c}
Carbohydrate (%).	16.30 ^{d}	19.00 ^{c}	20.25 ^{b}	23.40 ^{a}	21.10 ^{a}	21.55 ^{c}	22.90 ^{a}	22.95 ^{b}
Ash (%).	6.68 ^{a}	6.10 ^{ab}	5.55 ^{b}	5.46 ^{b}	6.57 ^{a}	6.31 ^{b}	6.26 ^{bc}	6.07 ^{c}
Fiber (%).	12.93 ^{a}	12.22 ^{ab}	11.85 ^{ab}	11.19 ^{b}	11.37 ^{a}	10.29 ^{a}	10.57 ^{a}	10.75 ^{a}
Moisture content.	4.00 ^{b}	4.55 ^{a}	4.62 ^{a}	4.50 ^{a}	6.10 ^{a}	5.75 ^{a}	5.87 ^{a}	6.90 ^{a}

HD_1= Harvesting at (R7) physiological maturity, HD_2= Harvesting at 7 days after R7, HD_3 = Harvesting at 14 days after R7, HD4= Harvesting at 21 days after R7

Means followed by the same letter (s) are not significantly different at 5% probability.

Seed viability vigors:

Results in Table 6 cleared that all tabulated seed viability and seed vigor parameters were significantly affected by harvesting dates in both seasons, except seedling length and seedling dry weight in 2019 season.

Highest germination percentage (83.75%) was result from the seed harvested at physiological maturity and reduced by 6.13%, 10.62% and 12.38 percent point, (as an average of the two seasons) when harvesting delayed up to 7, 14 and 21 after physiological maturity, respectively.

Normal seedling percentage take similar trend, but it significantly reduced for last harvesting date only in both seasons (Table 6). It reduced from 97.00%, for the seed harvested at physiological maturity to 87.00% (mean of both seasons) for the seed harvested at 21 days later on. Abnormal seedling showed an opposite trend significantly increased when seed harvested at last harvesting and estimated by 13.00% compared with 3.00% for the seed harvested at physiological maturity (Table 6).

With regard to seedling length and seedling dry weight which its significantly affected by harvesting date in 2018 season only, they reduced as harvesting date delayed after physiological maturity. Seedling length decreased from 8.52 cm to 6.56 cm (average of the two seasons) when harvesting delayed from physiological maturity to 21 days later on (Table 6). Seeding dry weight decreased from 2.03 gm to 1.66 gm on the same order. Concerning seedling vigor index-1 and SVI-II, results presented in Table 6 indicated that the highest value as observed for the seed harvested at physiological maturity, thereafter they gradually and significantly decreased when harvesting delayed to 7, 14 or 21 days after physiological maturity. As an average of the two seasons, the reduction estimated by 13.68%, 26.67% and 36.31% for SVI-I and by 15.29%, 21.76% and 32.35% for SVI-II when harvesting delayed to 7, 14 or 21 days after physiological maturity, respectively. This is a logic phenomenon because the seed germination%, seedling length and seedling dry weight were decreased by delaying harvesting date (Table 6).

Table 6. Effect of harvesting date on seed viability and vigor parameters of soybean in 2018 and 2019 season.

Germination characters:	2018 season				2019season			
	HD_1	HD_2	HD_3	HD_4	HD_1	HD_2	HD_3	HD_4
Seed germination (%)	87.50 ^{a}	78.75 ^{b}	76.25 ^{c}	70.00 ^{d}	80.00 ^{a}	72.50 ^{b}	70.00 ^{b}	68.75 ^{b}
Normal seedling (%)	97.50 ^{a}	99.00 ^{a}	97.25 ^{a}	85.50 ^{b}	96.50 ^{a}	98.00 ^{a}	95.50 ^{a}	88.50 ^{b}
Abnormal seeding (%)	2.50 ^{b}	1.00 ^{b}	2.75 ^{b}	14.50 ^{a}	3.50 ^{b}	2.00 ^{b}	4.50 ^{b}	11.50 ^{a}
Seedling length (cm)	9.07 ^{a}	8.38 ^{a}	6.90 ^{b}	6.86 ^{b}	7.97 ^{a}	7.98 ^{a}	7.47 ^{a}	6.27 ^{a}
Seedling dry weight (g/10 seedling)	2.10 ^{a}	1.94 ^{ab}	1.78 ^{b}	1.47 ^{c}	1.95 ^{a}	1.87 ^{a}	1.85 ^{a}	1.85 ^{a}
Seedling vigor index one (SVI- I)	7.94 ^{a}	6.59 ^{b}	5.27 ^{c}	4.80 ^{c}	6.38 ^{a}	5.77 ^{ab}	5.23 ^{b}	4.32 ^{c}
Seedling vigor index two SVI-II	1.83 ^{a}	1.52 ^{b}	1.36 ^{a}	1.03 ^{c}	1.56 ^{a}	1.35 ^{ab}	1.30 ^{ab}	1.27 ^{b}

HD_1= Harvesting at (R7) physiological maturity, HD_2= Harvesting at 7 days after R7, HD_3 = Harvesting at 14 days after R7, HD_4= Harvesting at 21 days after R7

Means followed by the same letter (s) are not significantly different at 5% probability.

Relationship between some climate factors and the studied traits:

The regression analysis was done to know the relationships between exposing period to field weathering, temperature and relative humidity as an independent factors and physical seed traits, seed constituents' traits and seed viability and vigor traits as dependent factors.

Number of days from flowering to harvesting:

Table 7 shows slope and R^2 values between days from flowering to harvesting and physical seed traits in 2018 and 2019 seasons. The results indicates that each increase in this period (within the range of thus experiment – see Table 1) would decrease green seed%, 500- seed weight and seed moisture content at harvesting, while seed of cracked seed coat percentage and electrical conductivity of seed leachates would be increase in both seasons. According to R^2 values, results in Table 7 indicates that the variations in this period, regardless of the other factors, were responsible for the major portion of variation in all physical seed traits, except normal seed % and defective seed%.

Concerning the seed constituents, the slop values indicates that the oil components, except carbohydrate content would be decrease with each increase in the period of flowering to harvesting (within the range of this experiment) in both seasons (Table 7). According to R^2 values, regardless of other factors, the variation in this period could explain the high percentage of variation in all seed constituents. With regard to seed viability and vigor traits, Table 7 indicates that each increase in flowering – harvesting period may cause a reduction in these traits with different figures according to the slope values. According to R^2 values the most variation in these traits is related to the variation in days from flowering to harvesting regardless all other factors (Table 7).

Table 7. Intercept, slope and coefficient of determination (R^2) between number of days from flowering to harvesting and physical seed traits, seed constituents, seed viability and vigor traits in 2018 and 2019 seasons**.**

Traits	2018 season			2019 season		
	intercept	slope	R^2	Intercept	slope	R^2
Physical seed traits						
Normal seed (%)	122.56	-0.5321	0.3355	93.464	-0.1571	0.2719
Defective seed (%)	- 22.561	0.5321	0.3355	7	0.15	0.2557
Green seed (%)	20.341	-0.2093	0.7901	9.3829	-0.1054	0.7396
Seed of cracked seed coat (%).	-19.861	0.3821	0.9891	- 35.339	0.5821	0.8523
500- seed weight(g)	96.35	-0.325	0.7358	84.625	-0.175	0.7758
Seed moisture content at harvesting (%)	141.09	-1.3321	0.9531	132.23	-1.2786	0.8728
Seed electrical conductivity.	- 53.12	1.045	0.9532	- 54.096	1.1179	0.8921
Seed constituents traits						
Oil content (%)	26.426	-0.0847	0.8052	37.309	-0.1953	0.7649
Protein content (%)	46.788	-0.1033	0.9152	0.9821	-0.1836	0.9821
Carbohydrate (%)	- 7.8057	0.3221	0.9765	13.993	0.0986	0.8941
Ash (%)	11.09	-0.0601	0.9275	8.1293	-0.0221	0.9423
Fiber (%)	16.417	-0.049	0.7983	12.607	-0.0226	0.1987
Seed viability and vigor traits						
Germination (%)	145.3	-0.7857	0.9584	115.54	-0.5179	0.8626
Normal seedling (%)	179.38	-1.0221	0.5706	125.86	-0.3786	0.6602
Seedling length (cm)	17.708	-0.1159	0.9027	14.034	-0.0801	0.8107
Seedling dry weight (g/10seedling)	4.3264	-0.0293	0.9689	2.2571	-0.0046	0.7529
Seedling vigor index one SVI-I	19.268	-0.1534	0.9621	13.345	-0.096	0.9859
Seedling vigor index two SVI-II	4.5619	-0.0366	0.9843	2.4543	-0.0131	0.8233

Number of days from flowering to threshing:

Results in Table 8 show the intercept, slope and coefficient of determination (R^2) between the exposing period (days) of parental plants to field weathering from flowering to threshing in 2018 and 2019 seasons. According to slope values, results indicated that each increase in this period, within the range of this experiment caused a decrease in some traits such as normal seed, green seed, 500-seed weight and seed moisture content at harvest. On the other hand, each increase in days from flowering to threshing could cause an increase in defective seed percentage, seed of cracked seed coat percentage and electrical conductivity of seed leachates (Table 8). According to R^2 values, it could be concluded that the variation in exposing period- participate by more than 70% of the variation in green seed, seed of cracked seed coat, seed moisture content at harvest percentage as well as 500- seed weight and EC of seed leachates in both seasons (Table 8). These values of R^2 reached to more than 85% (average of both seasons) for seed of cracked seed coat, seed moisture content at harvest and electrical conductivity of seed leachates (EC). On the other hand, the variation in normal and defective seed percentage due to the variation in exposing period relatively low (< 40%) as show in Table 8.

With regard to seed constituents, the slope values indicate that each increase in days from flowering to threshing (the exposing period for field weathering conditions), within the range of this experiment, caused reduction in oil, protein and each percentage and an increase in carbohydrate and fiber content (Table 8). However, according to R^2 values it could be concluded that the variation in the length of exposing period is responsible about more than 90% of variation in protein%, carbohydrate %, ash % and about 75-77% of variation in seed oil % in both seasons (Table 8).

Concerning the seed viability and vigor traits, the slope values indicate that each increase in days from flowering to threshing within the range of experiment caused a reduction in all traits tabulated in Table 8, except abnormal seedling. Moreover, the variation in number of days of this period participate by > 85% in variation in germination percentage, seedling length, seedling dry weight and seedling vigor indices and by 65-70% of the variation in normal seedling in both seasons (Table 8).

Table 8. Intercept, slope and coefficient of determination (R^2) between number of days from flowering to threshing and physical seed traits, seed constituents, seed viability and vigor traits in 2018 and 2019seasons.

Traits	2018 season			2019 season		
	intercept	slope	R^2	intercept	slope	R^2
Physical seed traits						
Normal seed (%)	143.5	-0.7402	0.373	100.81	-0.228	0.304
Defective seed (%)	- 43.50	0.7402	0.373	- 0.164	0.219	0.291
Green seed (%)	26.70	-0.2702	0.757	13.10	-0.139	0.687
Seed of cracked seed coat (%)	- 32.18	0.501	0.978	- 56.30	0.773	0.802
500- seed weight(g)	107.26	-0.431	0.744	92.33	-0.240	0.832
Seed moisture content at harvesting (%)	183.29	-1.739	0.933	179.31	-1.709	0.833
Seed electrical conductivity	- 86.12	1.363	0.932	- 99.16	1.538	0.902
Seed constituents traits						
Oil content (%).	28.98	-0.109	0.767	45.35	-0.271	0.784
Protein content (%).	50.22	-0.137	0.920	55.83	-0.252	0.986
Carbohydrate (%).	- 18.55	0.427	0.984	9.96	0.136	0.913
Ash (%).	12.97	-0.078	0.902	8.96	-0.028	0.904
Fiber (%).	-0.06	17.898	0.762	13.13	-0.027	0.194
Seed viability and vigor traits						
Germination (%)	170.98	-1.035	0.955	134.46	-0.691	0.819
Normal seedling (%)	160.93	-0.737	0.651	142.15	-0.533	0.697
Seedling length (cm)	21.33	-0.151	0.878	17.38	-0.112	0.838
Seedling dry weight (g/10seedling)	5.31	-0.039	0.983	2.19	-0.006	0.702
Seedling vigor index one SVI- I	24.13	-0.2004	0.943	17.38	*-0.131	0.982
Seedling vigor index two SVI-II	5.77	-0.048	0.988	2.93	-0.017	0.774

Day time temperature:

The simple regression analysis was done between average of day time temperature as independent factor and each physical seed traits, seed constituents and seed viability and vigor traits as dependent factors.

With regard to physical seed traits, results in Table 9 show that each increase in day time temperature during flowering to threshing period, within the range of this experiment, could cause an increase in normal seed %, green seed %, 500- seed weight and moisture content at harvesting. On the other hand, it may cause a decrease in defective seed percentage, seed of cracked seed coat percentage and EC value of seed leachates. According to the R^2 values valuable percentage of variation in seed of cracked seed coat (79.6% and 84.0%), 500-seed weight (82.2% and 79.3%) and EC (70.9% and 94.0%) in 2018 and 2019 seasons, respectively could be related to the variation in average day temperature during flowering to the threshing period. However, the figures were relatively low for normal seed, defective seed and green seed percentages.

With regard to seed constituents and according to slope values, results in Table 9 clear that each increase in day time temperature during the period from flowering to threshing, within the range of this study, caused an increase in seed oil content, protein, fiber and ash contents, while decrease the carbohydrate contents. According to R^2 values, it could be concluded that the variation in day time temperature during this period may cause a great portion of variation in protein content and carbohydrate contents, and relatively less portion of variation in oil and fiber contents.

Concerning the seed viability and vigor traits, results in Table 9 indicate that each increase in average day time temperature during the period from flowering to threshing within the range of this experiment could cause an increase in all tabulated traits according to the slope values. Moreover, the results also indicated that the variation in average day temperature participated by a valuable percentage in variation of germination % (77.8 % and 86.3%), normal seedling (89.8% and 62.1%), seedling length (67.7% and77.4%), seedling dry weight (95.8% and 75.9%), SVI-I (72.6 % and 96.1%) and SVI-II (87.6% and 82.0%) in 2018 and 2019 seasons, respectively (Table 9).

Table 9. Intercept, slope and coefficient of determination (R^2) between average of day time temperature during flowering to threshing period and physical seed traits, seed constituents, seed viability and vigor traits in 2018 and 2019 seasons.

Traits	2018 season			2019 season		
	intercept	slope	R^2	intercept	slope	R^2
Physical seed traits						
Normal seed (%)	- 231.58	9.37	0.683	17.96	1.92	0.233
Defective seed (%)	331.58	-9.37	0.683	79.37	-1.84	0.221
Green seed (%)	- 61.73	1.95	0.449	- 44.79	1.40	0.745
Seed of cracked seed coat (%)	152.22	- 4.234	0.796	261.06	-7.63	0.840
500- seed weight(g)	- 71.10	4.24	0.822	- 5.85	2.34	0.793
Seed moisture content at harvesting (%)	- 436.35	14.08	0.699	- 524.20	16.93	0.877
Seed electrical conductivity	402.64	-11.13	0.709	531.23	*-15.15	0.940
Seed constituents traits						
Oil content (%)	- 7.32	0.81	0.477	- 59.87	2.49	0.714
Protein content (%)	- 4.02	1.27	0.915	- 46.17	2.44	0.997
Carbohydrate (%)	144.55	-3.79	0.887	65.63	-1.34	0.943
Ash (%)	- 14.60	0.62	0.655	- 3.03	0.29	0.906
Fiber (%)	- 2.83	0.46	0.456	1.24	0.29	0.191
Seed viability and vigor traits						
Seed Germination (%)	**- 209.90**	**8.748**	**0.778**	**- 149.85**	**6.84**	**0.863**
Normal seedling (%)	- 171.84	8.099	0.898	- 63.24	4.85	0.621
Seedling length (cm)	- 32.99	1.239	0.677	- 26.24	1.03	0.774
Seedling dry weight (g/10seedling)	- 10.01	0.359	0.958	- 0.09	0.06	0.759
Seedling vigor index one SVI- I	- 48.01	1.645	0.726	- 35.31	1.25	0.961
Seedling vigor index two SVI-II	- 12.585	0.426	0.876	- 4.27	0.17	0.820

Average of relative humidity:

Results in Table 10 show that the magnitude of slope and R^2 become relatively different in the two seasons, this may be due to the average of relative humidity in the two seasons. It showed gradual increase in 2018 with each delay in harvesting date, but it tended to decrease from the highest value for HD_1 treatment to lower values for the HD_2 and HD_3 and returned to increase at HD_4 (Table 2).

With regard the physical seed traits and according to slope value, normal seed% green seed%, 500- seed weight showed negative response, while defective seed %, seed with cracked seed coat and EC showed positive response with the increase the relative humidity within the range of this experiment (30.6-81.5%) in 2018. Similar findings were found in 2019 season concerning normal seed %, 500 – seed weight and EC. Table 9 cleared that despite of another factors, the variation in relative humidity during flower to threshing participate with valuable percentage in variation of green seed % (86.8 and 84.4%), seed of cracked seed coat % (98.6 and 79.9%), 500-seed weight (71.5% and 79.9%) and EC (99.7% and 76.9%) in (2018and 2019), respectively, (Table10). However, these values were relatively low for normal seed% and defective seed percentages.

Concerning seed constituents, Table 10 shows different response for 2018 and 2019. In 2018 season slope values indicate that the increase in relative humidity during the period from flowering to threshing within the range of this experiment could decrease the oil, protein, ash and fiber % and increase carbohydrate%. An opposite trend was noticed in 2019, this may be due the different trend of relative humidity percentage in the two seasons. Also, the R^2 values in 2018 were higher than in 2019 (Table 10), the variation in relative humidity during this period responsible about the most variation in seed constituents in 2018 compared with 2019 (Table 10).

With regard to viability and vigor traits, similar trend of seed constituents was observed according to the slope and R^2 values. Positive response in 2019 and negative response in 2018 was observed in these traits due to the increase in relative humidity within the range of each season (Table 2). The variation in germination % seedling dry weight and seedling vigor index-II was high (< 78% in both seasons) due to the variation in relative humidity. This also was true for seedling length and seedling vigor index-I in 2018.

Table 10. Intercept, slope and coefficient of determination (R^2) between average of relative humidity during flowering to threshing period and physical seed traits, seed constituents, seed viability and vigor traits in 2018 and 2019 seasons.

Traits	2018 season			2019 season		
	intercept	slope	R^2	intercept	slope	R^2
Physical seed traits						
Normal seed (%)	442.98	-6.4771	0.215	97.028	-0.2946	0.0512
Defective seed (%)	- 342.98	6.4771	0.215	0.7414	0.3321	0.0671
Green seed (%)	190.94	-3.3364	0.8685	- 27.42	0.5009	0.8941
Seed of cracked seed coat (%)	- 314.86	5.8	0.9855	149.4	2.4365	0.7996
500- seed weight(g)	343.72	-4.8705	0.7147	58.717	0.2044	0.0567
Seed moisture content at harvesting (%)	1187.3	-20.535	0.9796	- 264.25	5.1862	0.7691
Seed electrical conductivity.	- 881.94	16.252	0.997	232.28	3.4602	0.4578
Seed constituents traits						
Oil content (%)	97.096	-1.3791	0.923	5.9844	0.2711	0.079
Protein content (%)	125.07	-1.542	0.8823	3.7882	0.5271	0.4336
Carbohydrate (%)	- 245.16	4.6888	0.8948	37.829	-0.2799	0.3861
Ash (%)	59.273	-0.9439	0.9881	2.0631	0.0756	0.5876
Fiber (%)	56.767	-0.7884	0.8938	- 1.1027	0.2112	0.9311
Seed viability and vigor traits						
Seed germination (%)	735.86	-11.642	0.9102	- 47.082	2.1368	0.7865
Normal seedling (%)	486.59	-6.9347	0.434	80.129	0.2584	0.0165
Seedling length (cm)	111.44	-1.8345	0.979	1.0903	0.1129	0.0861
Seedling dry weight (g/10seedling)	25.698	-0.422	0.872	0.680	0.021	0.882
Seedling vigor index one SVI- I	140.29	-2.374	0.996	- 8.631	0.250	0.359
Seedling vigor index two SVI-II.	31.722	-0.536	0.914	- 1.832	0.057	0.831

Average temperature:

The average temperature during the period from flowering to threshing as shown in Table 2 show different trend in 2018 and 2019. It was the high for HD_1 and low for HD_2 &HD_3 and returned to be high again for HD_4 in 2018. But in 2019 it showed gradual decrease from HD_1 up to HD_4 (Table 2). With regard to physical seed traits, their response to the change in average temperature during this period and within the range of this experiment (24.8-36.80 C° in 2018 and 21.41-36.15 C° in 2019) become relatively different in the two seasons according to the slope values. For example, normal seed %, green seed% and 500- seed weight would be decrease with an increase in average temperature in 2018 and vice versa in 2019. This may be due to the different magnitude of average temperature in the two seasons as mention before. Also, the R^2 values were relatively different in the two seasons, for example the variation in average temperature during flowering – threshing period was responsible about 98.3% of variation in normal seed in 2018 and only 20.8% in 2019. On other hand, these values were 17.16% and 97.35% for EC, 84.45% and 24.98% for seed of cracked seed coat %, 84.45 %, 56.26 % for 500-seed weight in2019 and 2018 seasons, respectively (Table 11).

Similar trend could be observed for seed constituents in relation to the average temperature during the period from flowering to threshing (Table 11). Negative response of all components, except carbohydrate, due to the increase in average temperature in 2018 and vice versa in 2019. However, and according to the R^2 values the variation in seed constituents due to the variation in average temperature was greater in 2019 than 2018, and with high values for protein and carbohydrate % followed by oil content (Table 11).

Regarding seed viability and vigor traits, the change in these traits due to the increase of average temperature was relatively different for most traits due to the different trend of average temperature during the period from flowering to threshing in the two seasons (Table 2). For example, according to the slope values germination % tended to decrease as average temperature increased in both seasons. However, normal seedling would be decrease in 2018 and increase in 2019 with each increase in average temperature within the range of this experiment (Table 11).

Moreover, according to R^2 values the variation percentage in germination %, seedling length, seedling dry weight and seedling vigor indices due to the variation in average temperature was greater in 2019 than in 2018, but the vice versa was observed for normal seedling percentage (Table 11).

Table 11. Intercept, slope and coefficient of determination (R^2) between average temperature during the period from flowering to threshing period and physical seed traits, seed constituents, seed viability and vigor traits in 2018 and 2019.

Traits	2018 season			2019 season		
	intercept	slope	R^2	intercept	Slope	R^2
Physical seed traits						
Normal seed (%).	529.5	-14.984	0.9835	30.64	1.7326	0.2081
Defective seed (%)	- 429.5	14.984	0.9835	68.046	-1.6913	0.2046
Green seed (%)	20.655	-0.603	0.0243	- 35.51	1.2578	0.6627
Seed of cracked seed Coat (%)	- 82.557	3.1585	0.2498	3.9679	2.3011	0.8445
500- seed weight(g)	209.68	-4.6735	0.5626	3.9679	2.3011	0.8445
Seed moisture content at harvesting (%)	297.05	-8.9372	0.1586	- 417.93	15.452	0.8026
Seed electrical conductivity	- 183.97	7.2929	0.1716	461.66	-14.718	0.9735
Seed constituents traits						
Oil content (%)	28.18	-0.298	0.0368	- 43.595	2.2515	0.6401
Protein content (%)	75.884	-1.256	0.5005	- 33.16	2.3116	0.9804
Carbohydrate (%)	- 80.549	3.3213	0.3838	59.714	-1.3062	0.9884
Ash (%)	17.129	-0.3703	0.13	0.2546	- 1.0245	0.7844
Fiber (%)	16.622	-0.1455	0.026	4.3392	0.2226	0.1216
Seed viability and vigor traits						
Seed germination (%)	276.86	-6.5819	0.248	6.2096	- 105.88	0.7808
Normal seedling (%)	423.25	-10.877	0.912	- 34.689	4.4936	0.5856
Seedling length (cm)	32.879	-0.8305	0.171	- 20.061	0.955	0.7248
Seedling dry weight (g/10seedling).	12.314	-0.3474	0.5042	0.3035	0.0548	0.6807
Seedling vigor index one SVI- I	39.468	-1.1034	0.184	- 27.561	1.1462	0.8849
Seedling vigor index two SVI-II	12.411	-0.3635	0.359	- 3.1132	0.1558	0.7283

DISCUSSION

Sowing with low quality seed is one of the reasons affect the plant population density in the field which may cause yield reduction. The low-quality seed is a result of seed deterioration which occurs with time due to exposure the plants during seed formation and maturity and / or during storage to external adverse conditions which induce a natural process involves cytological, physiological, biochemical and physical changes results in reduction in seed viability and seed vigor (Guleria *et al*., 2018). The present study indicated that the highest germination percentage and highest normal seedling was observed when soybean harvested at physiological maturity and they tended decrease significantly when harvesting delayed to 14 days after physiological maturity (Table 6). This was attributed with highest values of oil, protein contents (Table 5) and 500 -seed weight (Table 4). This was also in parallel with lowest values of seed of cracked seed coat and EC reading. This means the delay of soybean harvesting two weeks after or more after physiological harvesting may cause damage to seed coat and cell membrane and / or increase the respiration rate which causes some loss in seed reserves. This conclusion may be assessed by the high reading of EC test in solution of seed leachates of late harvesting dates compare with the earlier one.

The deterioration of seed produced from plants exposed to adverse condition during pre- and post – maturity may be due to less activity of anti-oxidation defense which was related to seed lipid peroxidation (Önder *et al.,* 2020). Saini *et al.* (2022) stated similar conclusions and found the lipid peroxidation can damage the cell membranes. In context Chhabra and Singh (2019) reported that the damage of cellular membrane cause seed deterioration due to loss of the seed constituents which could be measured by EC test of seed leachates. This phenomenon lead to reduction in seed viability and its vigor and associated with changes in the activity of enzyme system and accumulation of free radicals produced during metabolic process Li *et al.* (2022) stated that the reductive oxygen species (ROS) is one of the reasons of seed deterioration, its production increase in respiration rate which result in reduction in seed reserve. ROS also affects protein elasticity and membrane lipids which results in less seed viability (Nagar *et al.*, 2018). In context, Pinheiro *et al.* (2021) found that the seed deterioration due to field weathering was related to formation of intercellular spaces as a result of cell compaction, cell rupture in hourglass and parenchyma cell layers of weathered seed.

Pinheiro *et al.* (2023) stated that the decline in seed quality during field weathering has been associated to physical damage of the seed due to adverse environmental conditions. Also, the differences in seed deterioration among different soybean genotypes not only due to physical damage but also due to some biochemical and physiological aspects. Among these aspects generation of the oxyradicals in weathered seed in both susceptible and tolerant verities with higher rate in in susceptible one. This lead to lipid peroxidation and membrane integrity as well as EC field weathered seed. Also, the superoxide dismutase (SOD) activity, which play an antioxidants, decreased in weathered seed. This means the antioxidant defense system may also play a critical role in process of seed deterioration due to field weathering. Thus, in case of seed exposed to weathering, these antioxidants and oxidant enzymes are not able to quench high levels for free radicles as well as other peroxides generated during weathering, which leads to faster and sever damage.

CONCLUSION

From the obtained results, it could be concluded that the highest physiological activity of soybean seed was at physiological maturity and decreased significantly when harvesting delayed up to more than 14 days after physiological maturity. However, the highest figures of physical seed were observed at 7 days after physiological maturity. The length of exposing parental plants to field weathering factors has negative effects as well as seed viability and vigor. This was due to the day temperature than the other studied climate factors under the dry conditions of this study.

REFERENCES

Abdul-Baki, A. A., & Anderson, J. D. (1973). Vigor determination in soybean seed by multiple criteria 1. *Crop science*, *13*(6), 630-633.

Ali, I. M., Hamad, H. S., Nulit, R., & Mheidi, U. H. (2019). Biochemical And Physiological Changes of Soybean Seed (Glycine Max L. Merr.) Under Different Harvest Stages. *Biochemical and Cellular Archives*, *19*(Suppl. 1), 2223-2228.

A.O.A.C. (1983). Association of Official Seed Analysts. Seed vigor testing handbook: Contribution No. 32 to the Handbook on Seed Testing.

A.O.A.C. (1986). Rules for testing seed. Proc. Assoc. Off. Seed Anal., 6: 1126.

A.O.A.C. (1990) Association of Official Analytical Chemists. Washington DC, U.S.A.

A.O.A.C. (1995). Official methods of analysis. (16th Ed.) Gaithersburg, Maryland, USA: AOAC International.

A.O.A.C. (2000). Official Methods of Analysis of the Association of Official Analytical Chemists, 14 Ed. th Washington D.C. USA.

A.O.A.C. (2005) Official methods of analysis of AOAC International. *AOAC Official methods of analysis of AOAC International. AOAC International, Gaithersburg, MD, USA*.

Beyzi, S. B., Ülger, İ., Kaliber, M., & Konca, Y. (2018). Determination of chemical, nutritional and fermentation properties of citrus pulp silages. *Turkish Journal of Agriculture, Food Science and Technology*, *6*(12), 1833-1837.

Chhabra, R., & Singh, T. (2019). Seed aging, storage and deterioration: An irresistible physiological phenomenon. *Agricultural Reviews*, *40*(3), 234-238.

Delouche, J. C. (2021). Physiological changes during storage that affect soybean seed quality.

Dornbos, D. L. (2020). Production environment and seed quality. In *Seed quality* (pp. 119-152). CRC Press.

DuBois, M., Gilles, K. A., Hamilton, J. K., Rebers, P. T., & Smith, F. (1956). Colorimetric method for determination of sugars and related substances. *Analytical chemistry,* 28(3), 350-356.

FAO (2020). Available at http//www.Fao.org> food-agriculture.

Fialho, C. A., dos Santos Dias, D. C. F., Pinheiro, D. T., Gama, G. F. V., Soares, T. F. S. N., & da Silva, L. J. (2023). Physiological and sanitary quality of soybean seeds cultivars under harvest delay. *Revista de Ciências Agrárias*, *46*(4).

Guleria, H., Jyoti, B., Uniyal, A., & Trivedi, A. (2018). Screening of soybean germplasm standard germination and seed vigour test. *Annals of Horticulture*, *11*(1), 78-81.

ISTA. 1993. Hand book for seedling evaluation. International Seed Testing Association, Zurich, Switzerland.

Katembo, K. R. (2018). *Genetic analyses of pod shattering and agronomic traits of soybean (glycine max (l.) merr.) genotypes* (Doctoral dissertation, University of Nairobi).

Li, W., Niu, Y., Zheng, Y., & Wang, Z. (2022). Advances in the understanding of reactive oxygen species-dependent regulation on seed dormancy, germination, and deterioration in crops. *Frontiers in Plant Science,* 13, 826809.

Mstat, C. (1988). MSTAT-C, a microcomputer program for the design, arrangement, and analysis of agronomic research experiments. *Michigan State University, East Lansing, USA*.

Nagar, S.; Singh, M.; Billore, S. D.; Verma, R. K.; Kuchlan, P. and Chandra, S. (2018). Soybean Seed Germination: Factors Affecting and Ways to Minimize Germination Loss. *Popular Kheti,* 6(2), 13-17.

Önder, S., Tonguç, M., Güvercin, D., & Karakurt, Y. (2020). Biochemical changes stimulated by accelerated aging in safflower seeds (Carthamus tinctorius L.). *Journal of Seed Science*, *42*, e202042015.

Pinheiro, D. T., Dias, D. C. F. D. S., Medeiros, A. D. D., Ribeiro, J. P. O., Silva, F. L. D., & Silva, L. J. D. (2021). Weathering deterioration in pre-harvest of soybean seeds: physiological, physical, and morpho-anatomical changes. *Scientia Agricola*, *78*, e20200166.

Pinheiro, D. T., Dias, D. C. F. D. S., Silva, J. M. D., Gama, G. F. V., León, M. J. Z., & Silva, L. J. D. (2022). Assessment of the tolerance of soybean seeds to weathering deterioration in the pre-harvest phase by multivariate analysis. *Journal of Seed Science*, *44*, e202244035.

Pinheiro, D. T., Dias, D. C. F. D. S., Silva, L. J. D., Martins, M. S., & Finger, F. L. (2023). Oxidative stress, protein metabolism, and physiological potential of soybean seeds under weathering deterioration in the pre-harvest phase. *Acta Scientiarum. Agronomy*, *45*.

Poudel, S., Khatri, D., Pun Magar, L., KC, S., Mukherjee, A., Lucas, S., & Chiluwal, A. (2024). Final Seed Size in Soybean Is Determined during Mid-Seed Filling Stage. *Agronomy*, *14*(4), 763.

Raj, R. S., Ahamed, A. S., Sujatha, K., & Manonmani, V. Effect of Different Threshing Methods on Seed Quality of Little Millet cv. CO (Samai). *Journal homepage: http://www. ijcmas. com*, *10*(02), 2021.

Sachdev, S., Ansari, S. A., Ansari, M. I., Fujita, M., & Hasanuzzaman, M. (2021). Abiotic stress and reactive oxygen species: Generation, signaling, and defense mechanisms. *Antioxidants*, *10*(2), 277.

Saini, M., Yadav, R. R., Chandra, S., Kumar, A., Kumar, R., Sheoran, S., ... & Talukdar, A. (2022). Accelerated ageing test reveals quantitative nature of inheritance of seed viability in soybean [Glycine max (L.) Merr].

Staniak, M., Szpunar-Krok, E., & Kocira, A. (2023). Responses of soybean to selected abiotic stresses—Photoperiod, temperature and water. *Agriculture*, *13*(1), 146.