Physical and physiological quality of oat (*Avena sativa* L. cv. Turquesa) seeds

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ABSTRACT
Objective: The objective of this study was to determine the physical and physiological quality of a batch of oat (*Avena sativa* L. cv. Turquesa) seeds.
Design/Methodology/Approach: The following physical quality variables were evaluated: seed purity, weight of a thousand seeds, volumetric weight, and moisture content. Physiological quality was evaluated through a germination and emergence speed test, which also was used to measure seed vigor. A completely randomized experimental design, with factorial arrangement, and four repetitions was used. The factors analyzed were seed size (small and large) and aging (with and without aging).
Results: The following results were recorded: 99.52% seed purity; 34.31 g weight of a thousand seeds; 54.80 kg hl^{-1} volumetric weight; and 6.50% moisture content. Regarding treatment germination, no significant differences were found between the seed size and the size × aging interaction ($P=0.422$). The aging treatment reduced germination from 96.50% (unaged seeds) to 89.25% (aged seeds). The emergence speed did not show significant differences regarding seed size ($P=0.066$) and size × aging interaction ($P=0.868$). The aging treatment had a negative impact on the emergence rate. The aged seeds emerged at a 15.55 plants d^{-1} speed, while unaged seeds reached a 17.88 plants d^{-1} speed.
Study Limitations/Implications: This study only evaluated one batch of oat seeds.
Findings/Conclusions: The seeds have an adequate physical and physiological quality to establish oat crops. In addition, the seed batch was highly vigorous, because it maintained >80% germination rate after the aging treatment.

Keywords: germination, grain, speed of emergence, vigor.

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INTRODUCTION

In Mexico, oat (*Avena sativa* L.) is the most popular grain used as forage among the small grain cereals. From 1980 to 2021, the oat sowing area increased from 300,000 to >640,000 ha $year^{-1}$. Approximately 94% of this sowing area is used for forage production. The average yield during the same period reached 9.8 t ha^{-1} and Chihuahua, Durango, and Mexico were the main producer states (SIAP, 2022). Oat cultivation has mainly increased as a result of its adaptability to different agroclimatic conditions and the quality of its forage (Espitia-Rangel *et al.*, 2012).

The seed is a key supply for vegetal production and no agricultural practice can improve crops beyond the limits established by their germplasm (Camargo and Vaughn, 2021). A high-quality batch of seeds has a high germination capacity, vigor, size uniformity, and purity (Sabry, 2018).

Forage crops should be established as soon as possible. Consequently, the soil should be quickly covered to increase the efficient use of the water available in the soil (Rebolledo *et al.*, 2015) and the capacity of the plants to compete with weeds (Zhao *et al.*, 2006). Plants that grow from high vigorous seeds emerge faster and successfully establish themselves during the first development stages (Finch-Savage and Bassel, 2016).

Seed development comprises a series of ontogenetic stages, including fertilization, nutrient accumulation, seed drying, and dormancy. Each stage represents a change in the ontogenetic and physiological morphology that can alter the performance of the seed (Copeland and McDonald, 2001). The moment in which the seed reaches it maximum dry matter accumulation is known as physiological maturity (Copeland and McDonald, 2001). At this point, the seed reaches its maximum germination potential and records its highest vigor (Delouche, 1974). However, Copeland and McDonald (2001) determined that seeds reach their physiological maturity with a high moisture content (>12%); consequently, their crops should be harvested when they reach "harvest maturity" (≤12%). At this moment, the moisture level is appropriate for the storage of the seeds without incurring mechanical damages (Copeland and McDonald, 2001). Between the physiological and the harvest maturity, the grain is stored in the plant, where it can be exposed to adverse environmental conditions that can impact its quality (Copeland and McDonald, 2001). Seeds are not always sown immediately after the harvest, without being stored for a certain period; consequently, the storage time, the type of seed, and the environment of the warehouse (relative humidity, temperature, and oxygen levels) can impact the vigor of the seeds (Copeland and McDonald, 2001).

Determining the physical and physiological state of the seeds after a storage period is fundamental to guarantee the success of forage crops. Therefore, the objective of this study was to determine the physical and physiological quality of a batch of Turquesa oat seeds.

MATERIALS AND METHODS

This study was developed in the Laboratorio de Análisis de Semillas of the Postgrado en Recursos Genéticos y Productividad - Producción de Semillas, located in the Campus Montecillo of the Colegio de Postgraduados. The area is located at an altitude of 2,250 m and has a sub-humid warm climate, with summer rains. The mean annual temperature is 15 °C and the average precipitation is 645 mm (García, 1998).

A batch of *Avena sativa* L. cv. Turquesa seeds was acquired from the Bajío region, in Guanajuato, Mexico. The seeds were produced during the 2020 spring-summer cycle.

Four primary samples were taken from the batch of seeds, and they were mixed to obtain a composite sample (~1 kg). At the same time, a 300 g sample was taken to determine the moisture content of the seeds. The composite sample was homogenized in the lab and ~500 g was weighted and used as work sample. This latter sample was used to determine the physical and physiological quality of the seeds.

Following the methodology established by the ISTA (2018), the physical quality of the seeds was determined based on the quantity of pure seeds (PS), the weight of a thousand seeds (W1000S), the volumetric weight (VW), and the moisture (M) percentage.

Germination percentage (ISTA, 2018), accelerated aging (Delouche and Baskin, 1973, with some modifications by Huber *et al.* (1982) and Kim *et al.* (1985)), and speed of emergence (Maguire, 1962) were used to determine the physiological quality and vigor of the seeds.

During the physical quality analysis, a 2.8-mm sieve was used to separate large (L) from small (S) seeds; all the seeds that went through the sieve were considered S, while the seeds that remained in the sieve were classified as L. Four hundred seeds of both sizes were subject to accelerated aging (AA), while another 400 seed remained without the accelerated aging treatment (WAA). As a result of the combination of both factors (seed size and preparation), four treatments were established, with four repetitions each.

The sowing was carried out in a 2.5×1 m seedbed, with a substrate prepared with previously sterilized river sand. Twenty-five seeds were sown in each of the four rows of each repetition. The separation between the seeds and the rows was 3 cm. The distribution of the treatments and their respective repetitions was randomized within the seedbed.

The analysis of variance of the germination and the emergence speed was carried out using a completely randomized experimental design, with a factorial arrangement and four repetitions. Tukey's test ($P<0.05$) was used to compare the means. All the data were analyzed using the SigmaPlot 12.3 statistical package (Systat Software Inc. San Jose, CA, USA).

RESULTS AND DISCUSSION

The results of the physical analysis of the seed indicated a purity of 99.5% and an inert material content of 0.5%. The weight of a thousand seeds reached 34.31 g, 7.22 g more than the 27.09 g reported by Rodríguez-Herrera *et al.* (2020). That study recorded the average weight of a thousand oat seeds, with different doses and sources of fertilization. The variation in the nutrient supply impacts the development of the plant and the filling of the grain: larger seeds frequently produce better developed embryos and have more reserves for their maintenance (Carvalho and Nakagawa, 2000). In conclusion, the objective should be to obtain larger grains. The results obtained in this study fall within the range reported by Bobadilla *et al.* (2013), who recorded 33.80-38.34 g values in four oat varieties sown at different dates.

The volumetric weight obtained in this study was 54.8 kg hL^{-1}. Bobadilla *et al.* (2013) reported a volumetric weight between 42.63 and 46.19 kg hL^{-1} for four oat varieties, sown at different dates. A higher volumetric weight is associated with heavier, larger, and wider seed. This phenomenon could be related to late sowings because low temperatures during the flowering stage impact the development of the grain (Bobadilla *et al.*, 2013). The batch of seeds used in this study was produced during the 2020 spring-summer cycle, while the abovementioned study used seeds produced in winter.

The evaluated seeds recorded a 6.50% moisture, which is lower than the 12% recommended to prevent microorganism proliferation during the storage period (ISTA, 2018). A high moisture content at the time of arrival to the warehouse is the main cause of seed deterioration. Temperature and relative humidity in the warehouse are secondary factors; however, they become relevant if the seeds have a high moisture content (Pomeranz, 1992). The longevity of seeds with 5-14% moisture content increases by 50% per each 1% of lost moisture (Chala and Bekana, 2017).

The analysis of variance of the germination data did not record statistical differences between L and S seeds ($P=0.422$). There were no significant differences between seed size and aging interaction ($P=0.422$). However, the germination percentage between aging treatments (Figure 1) recorded significant statistical differences ($P<0.005$).

The WAA seed recorded a higher germination percentage than the AA seed. These results match the findings of Bobadilla *et al.* (2013), who reported that the aging treatment reduces 50-71% of the germination of four oat varieties, at different sowing dates. Tekrony (1995) mentioned that the germination percentage after the aging treatment can be used to classify the vigor of soy seeds: high vigor seeds have a >80% germination rate, medium vigor seeds have a 60-80% rate, and low vigor seeds have <60% rate. In addition, Nagel and Borner (2010) pointed out that 80% is a high germination percentage. In this study, >89% of the seeds subjected to the aging treatment germinated. Consequently, the batch of seeds evaluated in this research is considered as a highly vigorous batch.

The emergence speed did not record significant differences based on seed size ($P=0.066$) and the size × aging interaction ($P=0.868$). There were statistical differences between the different aging treatments (Figure 2).

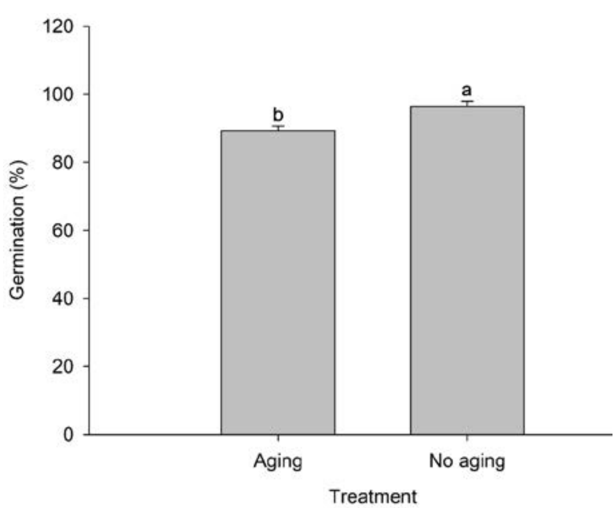

Figure 1. *Avena sativa* L. cv. Turquesa seed germination subjected to different accelerated aging treatments. Each bar shows the average of eight repetitions, with their respective standard error.

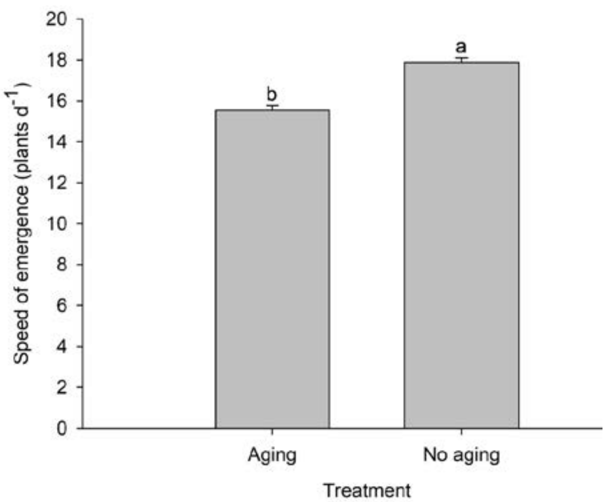

Figure 2. Emergence speed of *Avena sativa* L. cv. Turquesa seeds, using different accelerated aging treatments. Each bar shows the average of eight repetitions and their respective standard error.

Maguire (1962) defined emergence speed as a methodology used to evaluate seed vigor, under lab and field conditions. High values obtained with this expression indicate that one sample is more vigorous than the other (Ranal and Santana, 2006). The results of this study showed that, compared with the WAA, the AA treatment reduced the emergence speed of the plants by 13%. Based on the statistical differences, the seed used in this research can be classified as a highly vigorous seed.

The principle of the aging treatment is to increase the deterioration speed of the seeds. This process takes place through the 72 h exposition of the germplasm to a high temperature (40 °C) and a high relative humidity (100%). These two factors determine the intensity and the speed of the detriment of the seeds (Ohlson *et al.*, 2010). The main components of the reserve of seeds are lipids, proteins, and carbohydrates. The aging of seeds impacts the reserves at the cellular level. This phenomenon results in the degradation of the cell membrane, metabolic changes, reduction of the use of reserves, modification of proteins and enzymes, degradation of lipids and carbohydrates, and production of reactive oxygen species and other toxic compounds (Onder *et al.*, 2020). The loss of germination and vigor is the consequence of cell damages caused to the seed (Onder *et al.*, 2020).

The small seeds without aging treatment (SWAT) reached their emergence peak (74 plants) five DAS. Compared with SWAT, large seeds without aging treatment (LWAT) did not record such a high emergence peak (Figure 3); however, 47 and 46 plants emerged during the fifth and sixth DAS, respectively. During the sixth day, 91 plants had already emerged in SWAT, while LWAT recorded 93 plants.

Additionally, the small (SAA) and large (LAA) seeds subjected to the aging treatment started to emerge from five DAS. Nevertheless, these treatments reached their emergence peak during the sixth DAS (Figure 1): LAA recorded an accumulated emergence of 77 plants, while SAA recorded 82 plants. The SAA and LAA groups recorded 100% emergence (89.25 plants) until 12 DAS. For their part, SWAT and LWAT recorded their total plant emergence between 9 and 11 DAS.

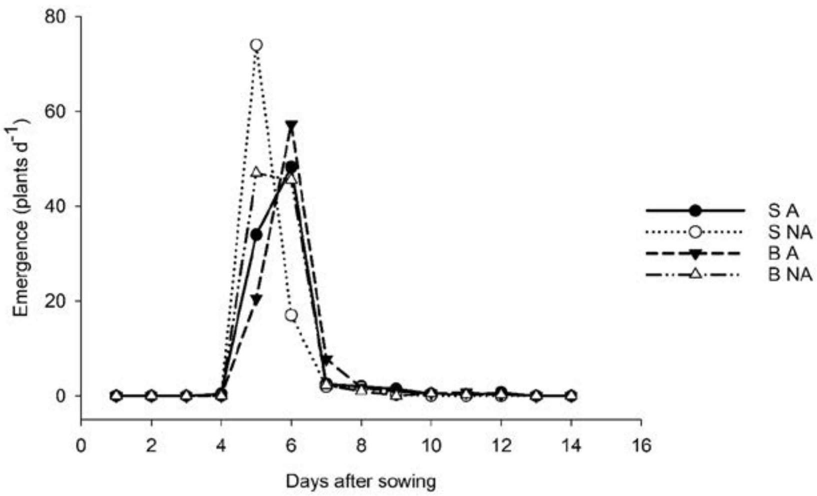

Figure 3. Emergence of *Avena sativa* L. cv. Turquesa plants grown from small (S) and large (L) seeds, subjected to aging treatment (AA) and without aging treatment (WAT), during 14 DAS. Each bar shows the average of four repetitions per treatment.

According to the proposal of Delouche and Baskin (1973), the aging treatments significantly reduce the germination and emergence speed of Turquesa oat seeds.

CONCLUSIONS

The batch of Turquesa oat seeds had the appropriate physical and physiological quality to establish oat crops for forage production. However, seed size did not record any effect on the germination percentage and the emergence speed. The aging treatment significantly reduced germination and emergence speed. Nevertheless, the seed recorded >80% germination after the aging treatment. Consequently, the evaluated seed is highly vigorous. Finally, the interaction between the study factors was not significant for germination and emergence speed.

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