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Utilization of proximal remote sensing as a non-destructive method for assessing the quality of corn seeds

Ariane Emanuele Dos Reis Rodrigues[1], Marco Antônio da Silva[1], José Dimas Rodrigues Oliveira[1], Gesivaldo Ribeiro Silva[1], Armando Lopes de Brito Filho[2], Maura Gabriela da Silva Brochado[1], Nádia Graciele Krohn[1], Franciele Morlin Carneiro[1*]

[1]Federal Technological University of Paraná (UTFPR), Santa Helena *campus*, Paraná State, Brazil.
[2]Western Paraná State University (UNIOESTE), Cascavel *campus*, Paraná State, Brazil.
*email: fmcarneiro@utfpr.edu.br

Abstract.

The physiological quality of corn seeds plays a key role in crop establishment. It directly influences final productivity. Although germination and vigor tests are well established, they have practical limitations. These tests are time-consuming. They require laboratory infrastructure and can involve destructive procedures. These factors limit their use in situations demanding faster, scalable assessments. In this scenario, proximal remote sensing has gained attention as a practical, non-destructive alternative. It is especially valuable in precision agriculture. Even so, limited information exists on the sensitivity of spectral indices to controlled seed deterioration. Measurement conditions, such as sensor positioning, may also influence results. Therefore, this study aimed to evaluate the potential of proximal remote sensing to estimate the germination and vigor of corn seeds subjected to accelerated aging. The experiment was carried out at the Seed Laboratory of the Federal Technological University of Paraná (UTFPR), Santa Helena campus, Paraná State, Brazil. A completely randomized design in a 5×4 factorial arrangement was used, with four replications. Treatments combined five aging periods (0, 24, 48, 72, and 96 hours) and four sensor heights (30, 40, 50, and 60 cm). Spectral data were collected using an active optical sensor (RapidScan, CS-45 model). This sensor operates in red, red-edge, and near-infrared regions. It allows calculation of vegetation indices such as NDVI (Normalized Difference Vegetation Index) and NDRE (Normalized Difference Red Edge). In this paper, we used only NDRE because it was more sensitive than NDVI in detecting changes associated with seed aging. This is likely because the red-edge region responds more to subtle variations in chlorophyll content. It is also linked to internal seed conditions associated with seed vigor. This index was then correlated with physiological variables, including germination percentage and the germination speed index. The data were analyzed using descriptive statistics, normality tests, analysis of variance, Tukey's test, and polynomial regression models. Model performance was evaluated using the coefficient of determination (R^2). Notably, the models performed consistently (R^2: 66.62%–76.00%). A sensor height of 60 cm yielded the best results, underscoring the importance of measurement configuration. Overall, the findings indicate that proximal remote sensing can be used as a fast, reliable, and non-destructive approach to estimate the physiological quality of corn seeds. Beyond confirming its potential, this study also shows that both seed aging and sensor positioning affect data quality. This is an important step toward standardizing data-collection protocols. In this sense, the approach can support more efficient monitoring systems. It enables faster decision-making, optimizes processes, and reduces operational costs. This work strengthens traditional methods and drives more efficient, sustainable, data-driven agriculture.

Keywords.
Germination Test, Precision Agriculture, Vegetation Indices.

Introduction

Traditionally, seed physiological quality and vigor are assessed through tests such as germination, electrical conductivity, and accelerated aging; however, these methods are often time-consuming and destructive (RIBEIRO et al., 2015; FESSEL et al., 2006). In this context, Proximal Remote Sensing (PRS) has emerged as a rapid, non-destructive, and sustainable alternative for evaluating seed physiological attributes through spectral reflectance analysis (ZOU et al., 2022; LAVEGLIA et al., 2024). The hypothesis of this study is that PRS can effectively detect physiological changes associated with seed deterioration and estimate the germination and vigor of aged corn seeds. Therefore, the objective was to evaluate the potential of PRS to estimate germination and vigor after accelerated aging, identify optimal NDRE assessment conditions, and compare its performance with conventional seed quality evaluation methods.

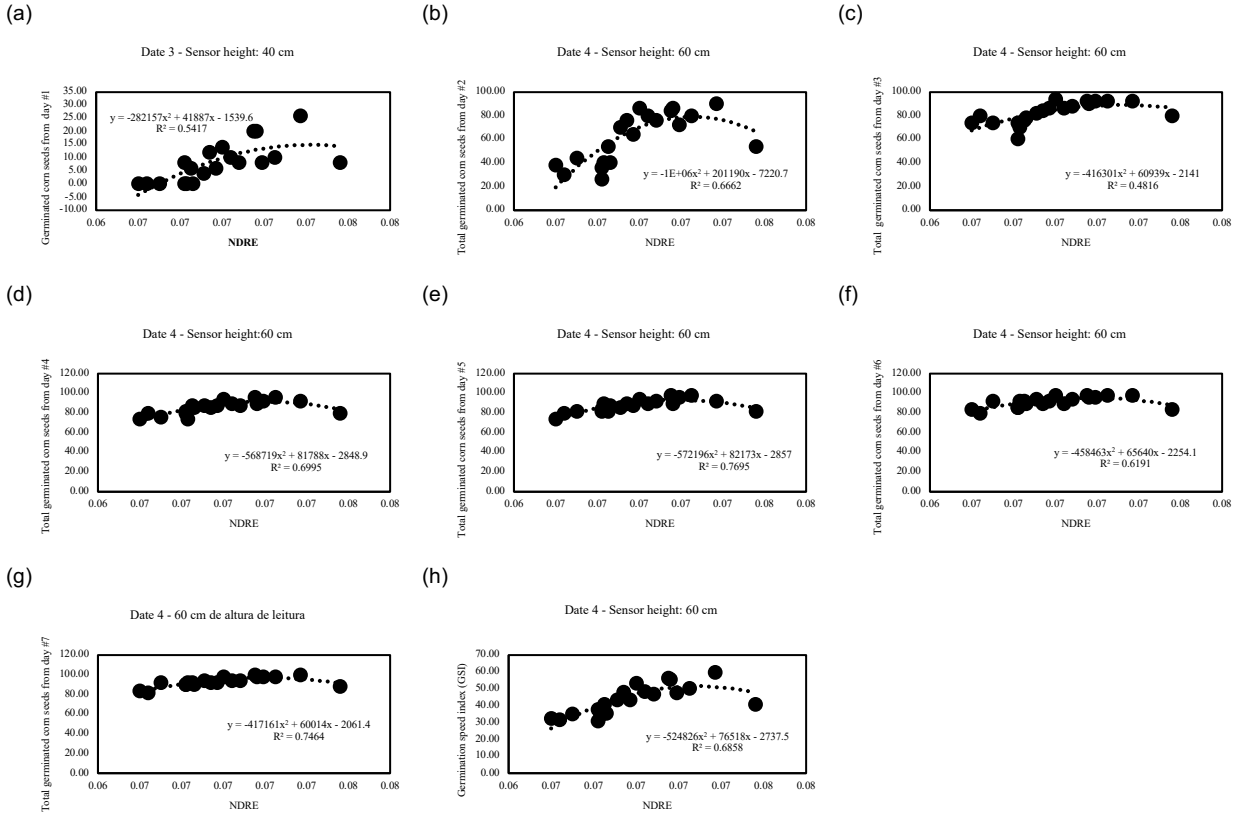
Material and Methods

The experiment was conducted at the Federal Technological University of Paraná (UTFPR), Santa Helena *campus*, under controlled laboratory conditions (27 °C and relative humidity between 95% and 100%). A completely randomized design was adopted in a 5 × 4 factorial arrangement, consisting of five accelerated aging periods (0, 24, 48, 72, and 96 h) and four sensor heights (30, 40, 50, and 60 cm), with four replications. Accelerated aging was performed by exposing corn hybrid P3282VYH seeds to 40 °C, followed by germination tests under controlled conditions to assess the effects of thermal stress on seed vigor and viability. The analyzed variables were germination percentage and the germination speed index (GSI). Spectral data were acquired using the RapidSCAN CS-45 active optical sensor, which measures reflectance in the red, red-edge, and near-infrared bands to calculate the NDRE vegetation index. Data were analyzed using descriptive statistics, Shapiro–Wilk normality tests, analysis of variance (ANOVA), and Tukey's test ($p \leq 0.05$). In addition, polynomial regression models were developed to estimate germination percentage and GSI based on NDRE values, and model performance was assessed using the coefficient of determination (R^2). Data processing and statistical analyses were conducted using AgroEstat and Microsoft Excel.

Results and Discussion

The results demonstrated that the NDRE vegetation index was effective in estimating both germination percentage and germination speed index (GSI) of corn seeds subjected to accelerated aging (Fig 1). Germination showed strong predictive performance, with coefficient of determination (R^2) values ranging from 66.62% to 76.95% across the evaluation dates, while GSI achieved an R^2 of 68.58%, indicating a consistent relationship between spectral responses and seed physiological performance. The highest predictive accuracy was observed on the sixth evaluation date, and sensor heights of 50 and 60 cm provided the most reliable measurements. In addition, seeds from the control treatment (0 h) and those aged for 24 h exhibited superior germination and vigor, confirming the sensitivity of NDRE for detecting physiological changes associated with seed deterioration and highlighting its potential as a rapid, non-destructive tool for seed quality assessment. These findings align with those of Pereira et al. (2020), who, using digital image processing on moringa seedlings and seeds, also achieved high performance in identifying physiological vigor.

Fig 1. Estimation of the biophysical characteristics of corn seeds: (a) germinated corn seeds from day #1, (b) total germinated corn seeds from day #2, (c) total germinated corn seeds from day #3, (d) total germinated corn seeds from day #4, (e) total germinated corn seeds from day #5, (f) total germinated corn seeds from day #6, (g) total germinated corn seeds from day #7, (h) germination speed index (GSI), based on the NDRE (Normalized Difference Red Edge Index).



Conclusions

The NDRE vegetation index was concluded to be an effective tool for estimating germination percentage and germination speed index (GSI) in corn seeds subjected to accelerated aging. The sixth evaluation date provided the highest predictive accuracy, with a coefficient of determination of 76.00%, indicating a strong relationship between spectral responses and seed physiological performance. In addition, sensor heights of 50 and 60 cm resulted in the best model performance. Overall, the findings confirm that proximal remote sensing using the NDRE index is a rapid, non-destructive, and reliable approach for assessing seed germination and vigor, highlighting its potential as a complementary alternative to conventional seed quality evaluation methods.

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