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DIFFERENCES IN GERMINATION AND FLOODING TOLERANCE AMONG CORN VARIETIES

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ABSTRACT

The present study sought to identify and evaluate the Germination Speed Index (GSI), the differences in growth and pigments in the hybrids Agroceres® (Hybrid AG 8780) and Pioneer® (Hybrid 30F53VYHR) submitted to stress by flooding in the vegetative stage. Two tests were carried out: in Trial I it was verified the GSI in both varieties, where it was found a higher germination tax and velocity for the variety Agroceres® (Hybrid AG8780). In Trial II, the plants that originated from Trial I were imposed to stress by flooding. From 3 DAF (Days After Flooding) it was evaluated: NDVI (Normalized Difference Vegetation Index), height, diameter of stem and visual analysis and, in the end of Trial II it was evaluated the photosynthetic pigment content. In the analysis of growth and photosynthetic pigment content, it was possible to verify that the Pioneer® (Hybrid 30F53VYHR) variety presented a better performance, with less variations when compared to the plants in control treatment, being more suitable for situations of stress by flooding.

Keywords: Abiotic stress, AG 8780, NDVI, 30F53VYHR, Visual analysis, *Zea mays*.

INTRODUCTION

With origin in the Central America region, corn has a great economic value, being the cereal with the most significant relevance in the planet, with an annual production of 1 billion tons (GARCÍA-LARA & SERNA-SALDIVAR, 2019).

Environment factors, such as a flood, have a direct impact on plantations and can cause significant losses (KUMAR et al., 2020) which highlights the necessity of studies directed at flood and soil use planning.

Flooding has become a recurring event due to climate changes, mainly when the soil is used in a non-planed manner, for example, with soil compaction due to agricultural machinery (LÖSCHNER & NORDBECK, 2019).

Depending on the stress imposed in the corn, its first signal of injury can be seen in the leaves and, afterward with difficulty in the assimilation of dioxide carbonate being able to alter its radicular development that, when bad develop, can decrease contact area of the plant with soil and nutrients (MAO et al., 2017), being able to cause the death of cells and organs, depending on the stress factor duration.

Thus, the present study sought to identify and evaluate the GSI, the differences in growth, visual and pigments in the hybrids Agroceres® (Hybrid AG 8780) and Pioneer® (Hybrid 30F53VYHR) submitted to stress by flooding in the vegetative stage.

MATERIAL AND METHODS

The study was accomplished in the Gragoatá Campus from the Universidade Federal Fluminense, located in Niterói, Rio de Janeiro State, Brazil. The region has a climate Aw, according to the Köppen classification (KOTTEK et al., 2006). The location has a latitude of 22°54’00’ S, longitude of 43°08’00’’ W and an altitude of 8 meters.

The seeds of corn Agroceres® (Hybrid AG 8780) and Pioneer® (Hybrid 30F53VYHR) were acquired through agricultural companies. The vases were initially filled with a layer of rocks to avoid soil loss in the base and facilitate drainage. The soil was added up to the eight litters marking in the vase.

After this initial phase, the referred work was divided into two trials for better comprehension. In Trial I: analysis of germination of seeds from different hybrids and in Trial II: flood of the plants originated from Trial I.

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Trial I: Germination of Corn Seeds

The corn (*Zea mays*) seeds Agroceres® (Hybrid AG 8780) and Pioneer® (Hybrid 30F53VYHR) were sowed in 8 litters vases. Each sample unity (vase) contained two seeds, being each treatment, with 22 repetitions (vases for each hybrid).

Tax of Germination and Germination Speed Index (GSI)

The rate of germination was measured every day and was counted the seeds that presented themselves visible, above soil (BRASIL, 2009; MORAES et al., 2012), being counted until the 12º day after sowing, when all treatments did not present any new germinated seeds.

It was determined the percentage of germination and the GSI. The germination percentage was calculated by formula proposed in the Regras para Análise de Sementes (BRASIL, 2009) and the GSI according to a formula adapted by Moraes et al. (2012).

Trial II: Flooding of Corn Plants

To carry out Trial II, the plants originated from Trial I stayed in their corresponding vases and were distributed in the same manner, randomly, with approximately 40 cm of distance between vases. The plants of the flooded treatment remained with water in the vases to provide flooding of the soil for 17 days, larger vases (18 litters) were purchased and later, the eight litter vases were added inside the 18 litters vases to contain the water.

Initially it was done a thinning, leaving only one plant per vase. Each treatment contained 11 repetitions each, totalizing 44 vases and 44 plants.

Afterwards, the flooding was carried out in the vases for the flooded treatment. For such, the vases of 18 litters were filled until the water in them went to the vases of eight litters, through holes in its base. During all the experiment period, it was maintained a water blade of 2.5 cm above the layer of soil. The plants in control treatment stayed in the eight litters vases, with irrigation in field capacity.

From the third day after flooding (3 DAF), the following were evaluated: NDVI, height, stem diameter, and visual analysis. The evaluations were repeated at 5 DAF, 8 DAF, 13 DAF, 15 DAF, and 17 DAF, as determined in preliminary experiments. At the end of Trial II, the photosynthetic pigment content was analyzed.

Analysis of the Normalized Difference Vegetation Index (NDVI)

To determine the NDVI, photos were taken during the experiment to verify different treatments vegetative action. For that, the concept of NDVI and application by ENVI® software was used as described by Cho (2019).

A cell phone camera took the photos and after were loaded in the ENVI® 4.5 software using the NDVI tool and choosing the bands of red and green. As it was impossible to acquire the infrared band, the green band replaced it as the green band is also reflected by plants (PRASANNAKUMAR et al., 2014).

It is important to highlight that, in an ideal situation, the value of +1 for the NDVI presents a higher production of biomass in the plant and a -1 represents a plant with no biomass production, that is, dead.

The data collected in the ENVI® software was a statistical analysis of the values along with the growth parameters.

Growth Parameters

During the experiment it was done a follow-up of height and diameter of stem of the plants. For the height, a graduated ruler was used in centimeters, measuring from the base of the sprout until its apical apex. For the diameter of the stem, it was used a digital caliper rule.

Visual Analysis

Throughout the experiment it was acquired photos of the plants in the flooded treatments that presented defensive mechanisms against the stress by flooding as a way to highlight if there was a variety more susceptible to the stress by flooding.

Photosynthetic Pigment Content

In the end of the experiment, it was also determined the photosynthetic pigment content, it was done spectrophotometrically in accord to Arnon (1949). Samples of 0.15 g of foliar tissue from the leaves were macerated in the presence of acetone 80% and estimated by the equations of Hendry & Grime (1993) and expressed in µmol gMF*1.

Experimental design and statistical analysis

The experimental design used in this study was internally random. The data were submitted to analysis of variance (ANOVA, p ≤ 0,05) and the averages were compared by Tukey's test (p ≤ 0,05) when there was a significative difference by the test F, with the help of the SISVAR® software.

RESULTS AND DISCUSSION

Trial I: Germination of Corn Seeds

The germination of corn seeds for both hybrids was 86% for the Pioneer® (Hybrid 30F53VYHR) variety and 95% for the Agroceres® (Hybrid AG8780) variety. The germination of seeds was stabilized with 4 and 3 days after the beginning of germination and the first day of germination was with 6 and 5 days after sowing (DAS) for the hybrids Pioneer® (Hybrid 30F53VYHR) and Agroceres® (Hybrid AG8780) respectively (Figure 1 A and B).

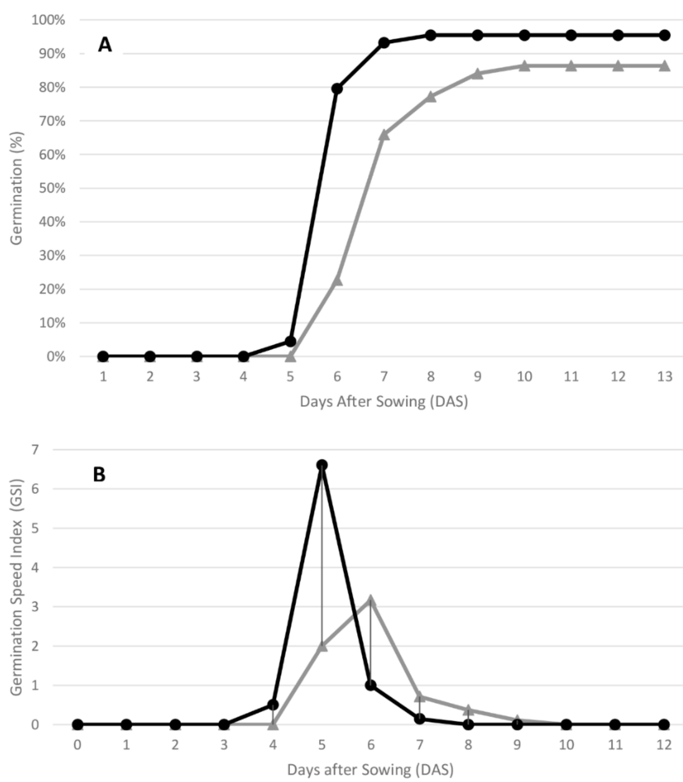

Figure 1. Percentage of germination for the varieties of corn (*Zea mays*) (-▲-) Pioneer® (Hybrid 30F53VYHR) and (-•-) Agroceres® (Hybrid AG8780) (A). Germination Speed Index (GSI) for the corn varieties (-▲-) Pioneer® (Hybrid 30F53VYHR) and (-•-) Agroceres® (Hybrid AG8780) (B).

It was possible to observe that the Agroceres® (Hybrid AG8780) variety had a better performance as to the GSI, the Agroceres® (Hybrid AG8780) variety had a higher germination velocity (8.39), showing a peak of germination velocity in the fifth DAS. As for the Pioneer® (Hybrid 30F53VYHR) variety, the highest germination velocity (3.44) occurred with six DAS.

Trial II: Flooding of Corn Plants

Growth Parameters

Initially the plants from the Agroceres® (Hybrid AG8780) variety in the flooded treatment showed higher growth when compared to the control treatment, presenting higher diameters, heights and NDVI. From the 15 DAF the plants in the control treatment presented better growth parameters, highlighting the NDVI with 8 DAF and 15 DAF that presented statistical differences when compared to the control treatment, showing a higher production of biomass (Figure 2 A).

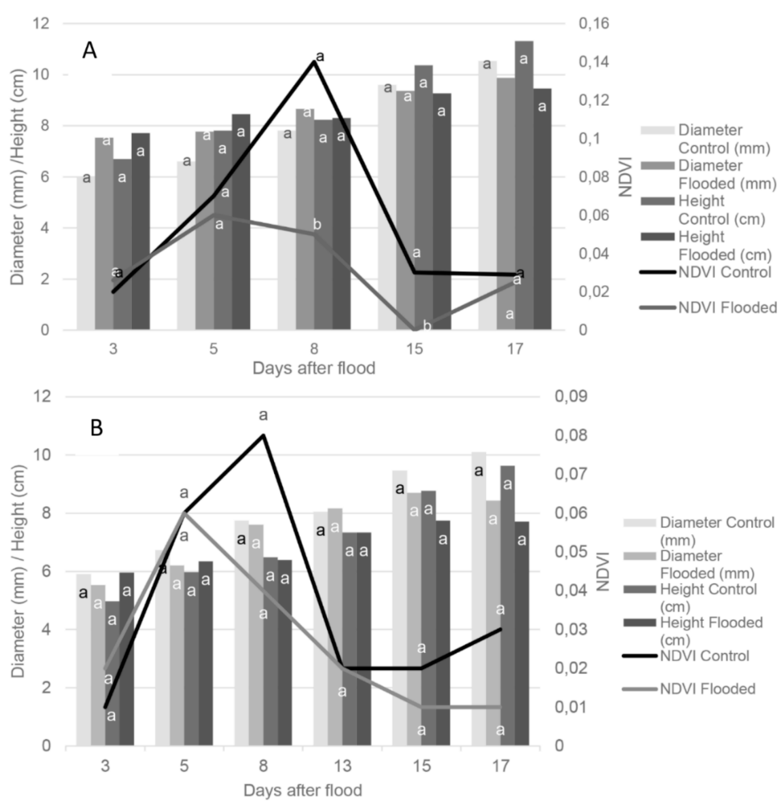

Figure 2. Variation in diameter, height, and Normalized Difference Vegetation Index (NDVI) for the varieties of corn (*Zea mays*) Agroceres® (Hybrid AG8780) (A) and Pioneer® (Hybrid 30F53VYHR) (B) in the control and flooded treatments. * Values followed by the same letters are not significantly different at $p \leq 0.05$ according to Tukey's test.

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The Pioneer® (Hybrid 30F53VYHR) variety presented some changes, especially in the NDVI with 8 DAF however, not in one moment was there a statistical difference between the flooded and control treatments (Figure 2 B).

Visual Analysis

With 3 DAF it was possible to observe some symptoms of stress caused by flooding in the plants as loss of color of leaves closer to the soil (Figure 3 A), change in leaves color (Figure 3 A) and root exit from the soil (Figure 3 B). The changes occurred in higher number for the Agroceres® (Hybrid AG 8780) variety.

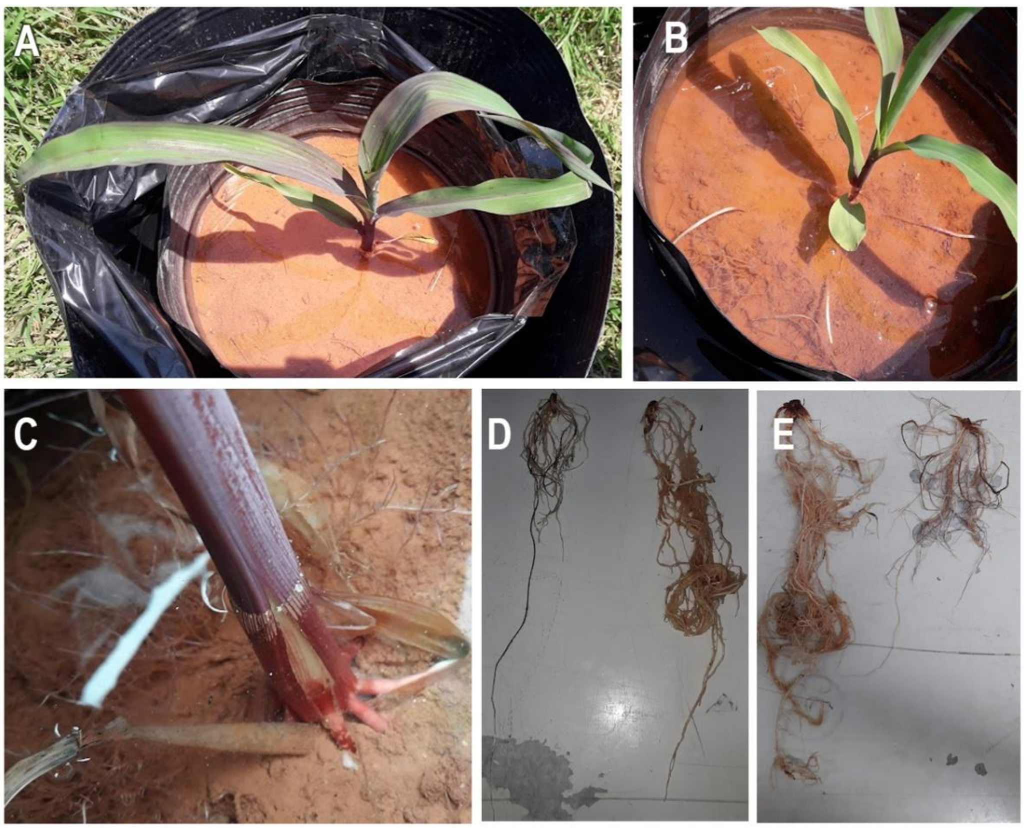

Figure 3. Plant of corn (*Zea mays*) in the treatment Agroceres® (Hybrid AG 8780) flooded with purple leaves (A). Plant of corn (*Zea mays*) in the treatment Agroceres® (Hybrid AG 8780) flooded with adventitious roots (B). Fissure (aerenchyma) in the base of the plant stalk of a flooded plant of the Agroceres® (Hybrid AG 8780) variety with 15 DAF (Days after flood) (C). Roots of the variety Pioneer® (Hybrid 30F53VYHR) with and without flood, respectively (D). Roots of variety Agroceres® (Hybrid AG 8780) without and with flood, respectively (E).

It was also observed that, with 5 DAF, the plants of the Agroceres® (Hybrid AG8780) variety presented a higher number of adventitious roots (Figure 3 B).

With the passing of days in stress, with 15 DAF it was possible to observe that, some of the plants of the Agroceres® (Hybrid AG8780) variety in the flooded treatment, possibly were in situation of anoxia, seeing that the plant searched for oxygen through a fissure at the base of the stem (Figure 3 C), response due to the formation of aerenchyma in the stem region (WANG & CAO, 2012).

With 17 DAF, it was possible to visually verify the variations between flooded and control treatments of Agroceres® (Hybrid AG8780) and Pioneer® (Hybrid 30F53VYHR), showing differences in growth and coloring in roots, with darker coloration and smaller size in the flooded treatments for both varieties (Figure 3 D and E).

Photosynthetic Pigment Content

It was possible to observe that there was no significative difference when comparing the averages of photosynthetic pigment content, in the same variety, between flooded and control treatments (data not shown).

For the control treatment, both varieties Agroceres® (Hybrid AG8780) and Pioneer® (Hybrid 30F53VYHR) showed similar averages, without significative differences between each other (data not shown).

When compared the two genotypes, in the flooded treatments, it was possible to verify that there was a significative difference for the pigment content *a*, *b*, carotenoids and total pigments with higher averages for the Agroceres® (Hybrid AG8780) variety showing that, despite not showing significant difference between them in the control treatment, when subjected to flooding stress the variety Pioneer® (Hybrid 30F53VYHR) had lower pigment content than the plants of the Agroceres® (Hybrid AG8780) variety (data not shown).

Lastly, even showing lower concentrations of chlorophyll *a* and *b* pigments, the variety Pioneer® (Hybrid 30F53VYHR) appears superior to the Agroceres® (Hybrid AG8780) variety, the pigments showed a minimal variation of averages between flooded and control treatments, with other parameters such as total leaf area and fresh and dry mass showing higher averages for the Pioneer® (Hybrid 30F53VYHR) variety, again demonstrating less accentuated changes than the

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Agroceres® (Hybrid AG8780) variety, fact observed in a previous study by our research group (CORREIA et al., 2021).

In Trial I turns out that, for the climatic conditions of Niteroi – RJ (Brazil) and in the experimental conditions, the highest tax and germination velocity occurred for the Agroceres® (Hybrid AG8780) variety when compared with the Pioneer® (Hybrid 30F53VYHR) variety.

This difference in germination velocity was due to the delay in germination which reflected in a lower germination percentage in the Pioneer® (Hybrid 30F53VYHR) variety, showing that the Agroceres® (Hybrid AG8780) variety had a better performance of tax and germination velocity.

In Trial II the plants did not present statistical difference in most of the growth parameters, except for the NDVI for the plants in the Agroceres® (Hybrid AG8780) variety with 8 DAF and 15 DAF where the flooded plants presented statistical difference when compared to the control treatment. This alteration was due to a lower investment in maintaining plant metabolisms, differing from the Pioneer® (Hybrid 30F53VYHR) variety that maintained itself at control level.

For the visual analysis, it was possible to verify that the plants of the Agroceres® (Hybrid AG8780) variety presented more significant changes. These reactions to the stressing factor occurred because the absorption of nitrogen and other nutrients present in the soil is impaired since the corn plants are dependent on diazotrophs bacteria for that, resulting in a purple color (in young leaves) or yellow (for older leaves) (MARENCO & LOPES, 2013).

In situations of low concentration of nitrogen, it is common the occurrence of accumulation of anthocyanin, a type of flavonoid that confers purplish colors to the plant, this accumulation of anthocyanin in the plant rises its tolerance to the deficiency of nitrogen (FALLAH et al., 2020).

The occurrence of adventitious roots is a common response to the flooding stress to increase the availability of oxygen in the radicular system and consequently increase the production of ATP (adenosine triphosphate), highly dependent on the presence of oxygen in the plant (HÜTHER et al., 2017).

All the visual alterations occurred in greater quantity in the Agroceres® (Hybrid AG8780) variety, showing again a greater difficulty in maintaining itself at control level, showing that its investment in the maintenance of metabolism in the plant was not as efficient as the Pioneer® (Hybrid 30F53VYHR) variety.

The alteration in the photosynthetic pigments demonstrates stress in the plant, this alteration can modify its performance (NASCIMENTO & MARENCO, 2010). When submitted to stress by flooding the Pioneer® (Hybrid 30F53VYHR) variety showed higher degradation of pigments than the Agroceres® (Hybrid AG8780) variety. The pigment content is involved in the light absorption, each pigment absorbs a different wavelength, its decrease entails in a lower absorption of energy by the plant (SOSNOWSKI & TRUBA, 2021), a fact confirmed in other studies by our research group (CORREIA et al., 2021).

Lastly, even with the alterations in the photosynthetic pigment content, when compared to the Agroceres® (Hybrid AG8780) treatment, the Pioneer® (Hybrid 30F53VYHR) variety presented a higher capacity of maintaining itself in control level, that is, demonstrated a higher investment in the maintenance of its metabolisms, being this variety the best recommended for situations of stress by flooding.

CONCLUSIONS

In Trial I it was verified that the higher tax and velocity of germination occurred for the Agroceres® (Hybrid AG8780) variety. In Trial II it was verified, by the parameters of growth, visual analysis and photosynthetic pigment content, that the Pioneer® (Hybrid 30F53VYHR) variety had a higher capacity of maintenance of growth and development in the situation of stress by flooding.

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