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CROP PRODUCTION

Physical attributes and yield of wheat seeds originated from plants under temporary flooding of the soil

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ABSTRACT: *The aim of this work was to evaluate whether there is any influence of temporary soil flooding on the agronomic performance and yield of wheat varieties. The experimental design was completely random blocks, in an 11x2 factorial scheme (eleven varieties and two soil water conditions), with four replications. Stress was imposed in the stage prior to plant anthesis. The assessments were made in two seasons (2016/2017) in relation to the number of spikelets in the main ear, number of seeds in the main ear, mass of seeds in the main ear, number of seeds in the tiller ear, mass of seeds in the tiller ear and yield in the useful area. The physical attributes number of seeds, seed mass and wheat seed yield, according to variety and agricultural year, are negatively affected by the temporary flooding (12 days) of the soil. There is influence of temporary soil flooding on the agronomic performance and yield of wheat varieties. The varieties TBio Toruk, TBio Sinuelo, TBio Sintonia, and CD151 are superior in soil flooding condition for the number of spikelets, number of seeds end for the seed mass attribute. In the soil at field capacity, the seeds produced have higher yield compared to those produced under flooding period, reaching about 309.2 Kg more for the variety TBio Sinuelo, 262 Kg for TBio Toruk and 114 Kg in CD1303.*
Key words: *Triticum aestivum, flood stress, productivity.*

Atributos físicos e rendimento de sementes de trigo originadas de plantas sob alagamento temporário do solo

RESUMO: *O trabalho teve como objetivo avaliar se há influência do alagamento temporário do solo no desempenho agronômico e no rendimento de cultivares de trigo. O delineamento experimental foi em blocos ao acaso, em esquema fatorial 11x2 (onze cultivares e duas condições hídricas do solo), com quatro repetições. O estresse foi o imposto no estádio antecedente a antese das plantas. Foi realizada a avaliação por dois anos (2016/2017) do número de espigueta da espiga principal, número de sementes da espiga principal, massa de sementes da espiga principal, número de sementes da espiga do perfilho, massa de sementes da espiga do perfilho e rendimento da área útil. Os atributos físicos número de sementes, massa de sementes e o rendimento de sementes de trigo, conforme a cultivar e ano agrícola, são afetados negativamente pelo alagamento temporário (12 dias) do solo. Há influência do alagamento temporário do solo no desempenho agronômico e na produtividade das variedades de trigo. As variedades TBio Toruk, TBio Sinuelo, TBio Sintonia e CD151 são superiores na condição de alagamento do solo para o número de espiguetas, número de sementes e para o atributo massa de sementes. Na condição de capacidade de campo, as sementes produzidas apresentam maior rendimento, atingindo cerca de 309,2 Kg a mais para a cultivar TBio Sinuelo, 262 Kg para a TBio Toruk e 114 Kg na CD1303 em comparação àquelas produzidas sob o período de alagamento imposto.*
Palavras-chave: *Triticum aestivum, estresse por alagamento, produtividade.*

INTRODUCTION

Wheat (*Triticum aestivum* L.) belongs to the Poaceae family and is one of the most cultivated cereals in the world. Both the diversity in the use of grains and its nutritional characteristics and the ease of storage make this species a staple food for approximately one third of the world population (SLEPER & POEHLMAN, 2006). Wheat production in Brazil is concentrated in the South Region, although it has expanded to the Midwest where it is cultivated under center-pivot irrigation. The total volume of grains produced in Brazil reached a value greater than 5 million tons in the 2018 season, however, does not meeting the consumer demand that is greater than 10 million tons, generating the need to import 6.4 million tons (CONAB, 2019).

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In lowland areas, monoculture production is considered a global problem (GARRITY & PERNITO, 1996), so the cultivation of wheat emerges as a highly relevant alternative to be used in the succession or rotation of other species, such as rice, in addition, successful cultivation contributes to the reestablishment of extensive areas that are affected by the infestation of invasive plants, such as red rice and rice grass (CALHEIROS et al., 2000).

In this context, lowland areas in Brazil have alluvial or hydromorphic soils, being able temporarily be flooded by the excess of rain that is associated with the deficiency of drainage, the elevation of the water table level and the presence of a textural horizon in the soil (LOPES et al., 1988). In Rio Grande do Sul, the cultivation of wheat in hydromorphic soils comes as an alternative to extensive livestock farming, which is generally practiced in these areas during the period of paousio to rice cultivation. In addition to the south of the country, cereal is also cultivated in central Brazil during the winter with the use of irrigation, due to the region offering good climate and soil conditions, in addition to its strategic market position, industrialization conditions and because it can be harvested in off-season production in the southern region (ALBRECHT et al., 2006).

In floodplain soils, flooding is one of the main abiotic stresses on the plant, being a limiting factor to crop yields (WANG et al., 2012). In those environments, unlike non-flooded soils, there is a limitation in the diffusion of gases and thus the cellular amount of oxygen can be reduced to levels that negatively affect aerobic respiration (FUKAO & BAILEY-SERRES, 2004), reflecting in low energy (WANG et al., 2012) with lactate and ethanol production (ZABALZA et al., 2009). The reduction of available energy affects the growth and productivity of plants (BAILEYSERRES & VOESENEK, 2008).

The effect of stress is dependent on the period imposed and the growth stage of the plant (REYNA et al., 2003). The flooding of the soil can reduce the quality of the seeds due to the reduction of the production and transport of carbohydrates, as well as, due to the lesser absorption of nutrients (KOZLOWSKI, 1997). According to PESKE et al. (2019), stress during in the seed filling phase and the vegetative phase results in reduced productivity and smaller seeds. VERNETTI JUNIOR (2009) reported that the greatest sensitivity to flooding occurs at the beginning of the seed filling phase. However, it must be considered that the effect of stress depends on the variety, intensity, and duration of the stress (AUMONDE et al., 2017).

Having this context, the objective of this work was to evaluate whether there is influence of the temporary flooding of the soil on the agronomic performance and the yield of different wheat varieties.

MATERIALS AND METHODS

The experiment was carried out in the Experimental Field of the Federal University of Pelotas, located at the Capão do Leão Campus, in the geographical location of 31° 52' S and 52° 21' W, being the performance attributes analyzed in the Seeds Analysis Laboratory of the Post-Graduation Program in Seed Science and Technology at the Department of Phytotechnics.

Eleven wheat varieties (*Triticum aestivum* L.) were used to obtain the seeds used to determine the response to the periods of flooding of the soil, being: TBio Sinuelo, TBio Sintonia, TBio Mestre, TBio Noble, TBio Toruk, CD1303, CD1440, CD1550, CD1252, CD150 and CD151, which were cultivated in two different seasons (2016/2017) and in the same area with Hydromorphic Planosol soil type and a sandy-loam texture (EMBRAPA, 1999). The nutritional and acidity soil correction was carried out according to soil analysis and the recommendation of the Fertilization and Liming Manual for the States of RS and SC (2004).

The spacing between rows was 17 centimeters, resulting in a population density of 330 seeds per m^2. After the end of the development cycle, at 123 days after sowing, 10 plants were removed from each repetition for the evaluation of yield attributes and the rest of the useful plot area was manually harvested for yield evaluation. The ears were taken for drying in an oven up to 12% humidity, after the seeds were threshed manually and stored in a cold, dry chamber (10 ± 2 ºC and 33% RH), in order to maintain their physiological potential.

For the establishment of the soil flooding, bunds were built around each plot in order to hold the water inside. The period of flooding was imposed in the stage prior to plant anthesis, by the maintenance of the water depth at 20 millimeters above the ground and inside each plot. After the period of 12 days, the bunds were opened and the water layer was removed for soil drainage.

In order to evaluate the effect of the flooding period on the wheat seed yield attributes, the following analyzes were done:

a) Number of spikelets: manually counted at the main ear.

b) Number of seeds in the main ear: after counting the spikelets, the number of seeds was counted by manual threshing.

c) Mass of seeds in the main ear: after the counting,

the seeds mass was measured on a precision balance and the result expressed in grams (g).
d) Number of seeds in the tiller ear: threshing was carried out manually, and the number of seeds was counted.
e) Mass of seeds in the tiller ear: after the counting, the seeds mass was measured on a precision balance and the result expressed in grams (g).
f) Yield in the useful plot area: performed after harvest, where ears were dried, threshed and having the mass of each plot measured by a precision balance, the result being expressed in kilograms (Kg).

The experimental design adopted was completely randomized blocks with eleven varieties, two water conditions (field capacity/no flooding and temporary flooding) and four replicates. The data obtained were submitted to the assumptions of homogeneity of variances using the Bartlett test and normality using the ShapiroWilk test. After meeting the assumptions of homogeneity and normality, the data were subjected to analysis of variance and, if significant at 5% probability by the F test, subjected to mean analysis by the Scott Knott test at 5% probability, using the SISVAR statistical software.

RESULTS AND DISCUSSION

In the first season (2016), for the number of spikelets from the main ear, when the plants were kept in field capacity condition, showed superior behavior the varieties TBio Sinuelo, Tbio Sintonia, Tbio Noble, Tbio Toruk and CD1252 while, in the condition of soil flooding, the varieties TBio Toruk and Tbio Sinuelo obtained superiority in relation to others (Table 1).

The number of seeds in the main ear of the varieties TBio Sinuelo and TBio Toruk got was higher values on field capacity condition. Similarly, to the soil flooding condition, TBio Sinuelo and TBio Toruk was superior were superior compared to the other cultivars tested (Table 1).

Regarding the seed mass of the main ear, for a field capacity condition, the varieties TBio Sinuelo, TBio Noble, TBio Toruk, CD1252 and CD150 obtained higher values. In the soil flooding condition, only one cultivar Tbio Toruk presented a greater increase in seed mass compared to the other varieties (Table 1). For the number of seeds per tiller, in field capacity the varieties TBio Sinuelo and TBio Toruk were superior to the others. (Table 1). When submitted to soil flooding, TBio Sinuelo, Tbio Toruk and Tbio Mestre demonstrated superiority, while TBio Noble, CD1252, CD150 and CD151 obtained the lowest values for an analyzed variable (Table 1).

For the variable of seed mass produced by tillers maintained under field capacity condition, the varieties TBio Sinuelo and TBio Toruk demonstrated increase in seed mass. In the flooding condition, TBio Sinuelo, Tbio Mestre e TBio Toruk a greater increase in seed mass compared to other varieties (Table 1).

For the yield of seeds, harvested in the useful area of the plots, it was observed a superiority of the variety TBio Sinuelo when maintained in field capacity. And for flooding, the highest seed yield was processed by variety CD1440. On the other hand, varieties TBio Noble and CD150 obtained the lowest values for seed yield per useful area, when in field capacity and under flooding, respectively (Table 1).

The production of carbohydrates and energy that is intended for the structural maintenance of the plant, growth and productivity, are directly related to the execution of adequate nutrition, management and cultural treatments, strategic choice of cultivars, population as well as the plant architecture and vitality of the sheets (AUMONDE et al., 2017). In this sense, appropriate conditions of soil, climate, management and cultural treatments, as well as the choice of cultivars suitable for each environment, favor the attainment of greater productive ceilings.

Soil flooding can change plant physiology by affecting the rate of oxygen diffusion in the soil and reducing its availability to plant roots (BALAKHNINA et al., 2010). The response to production and accumulation of toxic compounds is closely related to the species, cultivar and detoxification capacity of each plant.

In the second wheat season (2017), for the assessment of number of spikelets in the main ear, in plants maintained at field capacity, the superior varieties were TBio Sinuelo, TBio Mestre, TBio Noble, TBio Toruk, CD1303, CD1252 and CD150, while the variety CD1440 was inferior, obtaining the lowest value for the analyzed variable. To flooding condition, the varieties that achieved superiority were TBio Sintonia, CD1252, CD150 and CD151, while the varieties TBio Meste, TBio Noble, TBio Toruk and CD1550 obtained lower values (Table 2).

For the number of seeds in the main ear, the varieties TBio Sinuelo, TBio Mestre, TBio Noble, TBio Toruk, CD1303 e CD150 maintained in soil at field capacity showed a greater number of seeds, whereas CD1252 and CD151 showed the lowest results. In the flooding condition, the varieties that showed higher values were TBio Sinuelo, TBio Sintonia, CD1440 e CD151 in relation to TBio Mestre, TBio Noble, TBio Toruk, CD1303, CD1550, CD1252 e CD150 (Table 2).

The seed mass in the main ear for a field capacity condition was higher in varieties TBio

Table 1 - Number of spikelets in the main ear (SPMEc), number of seeds in the main ear (SEMEc), seed mass in the main ear (SMMEc), number of seeds in the tiller ear (SETE), seeds mass in the tiller ear (SMTE), yield in the useful plot area, of wheat varieties submitted to temporary soil flooding, in the 1st season of evaluation.

	----------SPMEc----------		----------SEMEc----------		----------SMMEc (g)----------	
Varieties	FC	FL	FC	FL	FC	FL
TBio SINUELO	15.8 Aa	15.7 Aa	42.2 Aa	38.4 Aa	1.6461 Aa	1.4546 Ba
TBio SINTONIA	15 Aa	15.4 Ba	31.8 Ba	30.2 Ba	1.2777 Ba	1.1800 Ca
TBio MESTRE	13.5 Ba	14.4 Ba	31.1 Ba	34.0 Ba	1.1790 Ba	1.0014 Ca
TBio NOBLE	15.2 Aa	13.6 Bb	30.8 Ba	28.3 Ba	1.5549 Aa	1.0806 Cb
TBio TORUK	15.3 Aa	16.4 Aa	42.9 Aa	43.8 Aa	1.7296 Aa	1.7593 Aa
CD1303	13.4 Ba	13.4 Ba	26.2 Ba	25.0 Ba	1.1128 Ba	1.0870 Ca
CD1440	13.5 Ba	13.5 Ba	27.0 Ba	26.4 Ba	0.9952 Ba	0.9794 Ca
CD1550	13.7 Ba	13.6 Ba	31.8 Ba	31.7 Ba	1.1927 Ba	1.1628 Ca
CD1252	15.4 Aa	14.3 Ba	28.3 Ba	28.2 Ba	1.4692 Aa	1.2796 Ca
CD150	14.1 Ba	14 Ba	29.3 Ba	31.8 Ba	1.4291 Aa	1.4460 Ba
CD151	13.9 Ba	14.2 Ba	32.0 Ba	33.6 Ba	1.3454 Ba	1.3635 Ba
CV(%)	----------10.3----------		----------23.3----------		----------26.2----------	
	----------SETE----------		----------SMTE (g)----------		--------yield in the useful area (Kg)-------	
Varieties	FC	FL	FC	FL	FC	FL
TBio SINUELO	58 Aa	58 Aa	2.9829 Aa	2.0718 Ab	437.6 Aa	128.4 Fb
TBio SINTONIA	10 Cb	32 Ba	0.2876 Cb	1.1687 Ba	339.6 Da	329.3 Bb
TBio MESTRE	36 Ba	54 Aa	1.2891 Ba	1.4225 Aa	247.9 Fa	158.8 Eb
TBio NOBLE	28 Ca	3 Cb	0.9154 Ca	0.1258 Ba	114.4 Ja	98.1 Gb
TBio TORUK	58 Aa	54 Aa	2.3809 Aa	2.1845 Aa	363.1 Ca	101.1 Gb
CD1303	13 Ca	25 Ba	0.5428 Ca	1.0123 Ba	393.1 Ba	279.3 Db
CD1440	16 Ca	26 Ba	0.5234 Ca	0.9101 Ba	209.1 Gb	366.1 Aa
CD1550	43 Ba	31 Ba	1.5966 Ba	1.0283 Ba	319.0 Ea	157.7 Eb
CD1252	19 Ca	18 Ca	0.7320 Ca	0.7286 Ba	153.4 Hb	290.8 Ca
CD150	16 Ca	9 Ca	0.6588 Ca	0.3123 Ba	132.5 Ia	90.9 Hb
CD151	29 Ca	13 Ca	1.1235 Ba	0.4862 Ba	154.1 Ha	128.2 Fb
CV(%)	----------70.1----------		----------84.4----------		----------2.2----------	

*Means followed by the same uppercase letter in the column and lowercase in the row do not differ by Scott Knott test at 5% probability. FC = field capacity; FL = flooding.

Sinuelo, Tbio Mestre, TBio Noble and Tbio Toruk and lower in varieties CD1252 and CD151. When comparing the varieties in the condition of flooding, it is noted that TBio Sinuelo, TBio Sintonia, CD1440, CD150 and CD151 produced higher mass compared to the other varieties (Table 2). Regarding the number of seeds in the tiller, TBio Sinuelo, TBio Toruk and CD1303 showed a higher number when kept in field capacity, while under flooding the variety with the highest value was CD151 (Table 2).

For the variable seed mass in tiller at field capacity, the varieties TBio Toruk and CD1303 showed higher values. However, in the flooding condition, CD151 stood out compared to the other varieties (Table 2).

The maintenance of crop productivity is associated with the ability to defend and overcome the stress faced. In this context, to tolerate the stress imposed, plants can present morphological, anatomical or metabolic strategies, which guarantee the use of energy in order to prolong their survival under waterlogged soil (PERATA et al., 2011; SHINGAKI-WELLS et al., 2011).

On the other hand, regarding the yield in the useful area harvested, it was observed that the variety CD151 at field capacity was superior the others. Under soil flooding, CD1303, CD1440, CD151 and CD1252 showed higher yield value (Table 2).

In the condition of field capacity, the seeds produced have higher yield compared to those produced under flooding period, reaching 309.2 Kg more for the variety TBio Sinuelo, 262 Kg for TBio Toruk and 114 Kg in CD1303.

Productivity can be negatively affected by soil flooding stress depending on the species and

Table 2 - Number of spikelets in the main ear (SPMEc), number of seeds in the main ear (SEMEc), seed mass in the main ear (SMMEc), number of seeds in the tiller ear (SETEf), seeds mass in the tiller ear (SMTEf), yield in useful plot area, of wheat varieties submitted to temporary soil flooding, in the 2nd season of evaluation.

	----------SPMEc----------		----------SEMEc----------		----------SMMEc (g)----------	
Varieties	FC	FL	FC	FL	FC	FL
TBio SINUELO	15 Aa	14 Ba	33 Aa	27 Ab	1.1067 Aa	0.7975 Ab
TBio SINTONIA	13 Bb	16 Aa	23 Bb	30 Aa	0.7011 Ba	0.7490 Aa
TBio MESTRE	15 Aa	11 Cb	31 Aa	18 Bb	0.9520 Aa	0.3637 Bb
TBio NOBLE	15 Aa	10 Cb	31 Aa	16 Bb	1.0838 Aa	0.3913 Bb
TBio TORUK	15 Aa	10 Cb	31 Aa	14 Bb	1.2105 Aa	0.3471 Bb
CD1303	15 Aa	15 Ba	27 Aa	21 Bb	0.8479 Ba	0.4917 Bb
CD1440	11 Cb	14 Ba	22 Bb	28 Aa	0.7740 Ba	0.7660 Aa
CD1550	13 Ba	12 Ca	23 Ba	18 Ba	0.7311 Ba	0.3977 Bb
CD1252	14 Ab	17 Aa	19 Ca	18 Ba	0.5371 Ca	0.3763 Ba
CD150	15 Aa	16 Aa	29 Aa	22 Bb	0.8132 Ba	0.7762 Aa
CD151	13 Bb	16 Aa	16 Cb	29 Aa	0.3759 Cb	0.8563 Aa
CV(%)	----------13.8----------		----------28.5----------		----------36.3----------	
	----------SETEf----------		----------SMTEf (g)----------		---------Yield in the useful area (Kg)---------	
Varieties	FC	FL	FC	FL	FC	FL
TBio SINUELO	40 Aa	19 Bb	1.0086 Ba	0.3815 Bb	355.4 Ba	285.7 Cb
TBio SINTONIA	0 Ca	0 Ca	0 Da	0 Ca	354.9 Ba	309.8 Bb
TBio MESTRE	0 Ca	0 Ca	0 Da	0 Ca	355.8 Ba	247.7 Db
TBio NOBLE	26 Ba	0 Cb	0.7699 Ba	0 Cb	331.1 Ca	282.7 Cb
TBio TORUK	46 Aa	0 Cb	1.5345 Aa	0 Cb	347.6 Ba	301.5 Bb
CD1303	35 Aa	0 Cb	1.3215 Aa	0 Cb	362.3 Ba	333.1 Ab
CD1440	0 Ca	0 Ca	0 Da	0 Ca	307.1 Da	320.6 Aa
CD1550	19 Ba	0 Cb	0.4598 Ca	0 Cb	361.4 Ba	293.7 Cb
CD1252	0 Ca	0 Ca	0 Da	0 Ca	355.7 Ba	333.5 Ab
CD150	27 Ba	0 Cb	0.8004 Ba	0 Cb	343.6 Ba	261.3 Db
CD151	0 Cb	39 Aa	0 Db	0.9745 Aa	389.5 Aa	324.2 Ab
CV(%)	----------47,7----------		----------58,7----------		----------3,8----------	

*Means followed by the same uppercase letter in the column and lowercase in the row do not differ by Scott Knott test at 5% probability. FC = field capacity; FL = flooding.

cultivar used. This reduction can be related, among other factors, to the limitation in the absorption of water and minerals, which compromises the development of plants (LIU et al., 2011). In addition, stress can decrease carbon assimilation by the plant, as well as altering the partition and allocation of carbon (CHAVES et al., 2002). With flooding, the plant can modify the relationship between source and drain, investing a smaller input of assimilates in the "filling" of seeds, which justifies the results obtained, in which the physical attributes and yield were negatively affected by stress. In general, in cereals, water stress conditions can negatively affect grain quality and yield, due to reduced photosynthetic rates and dry matter accumulation, determined by the drain force (RAJJOU et al., 2012).

CONCLUSION

The physical attributes of number of seeds, seed mass and wheat seed yield, according to variety and season, are negatively affected by the temporary flooding of the soil. The varieties TBio Toruk, TBio Sinuelo, TBio Sintonia and CD151 are superior in condition of flooding of the soil, for number of spikelets, number of seeds and for the seed mass attribute. In the condition of field capacity, the seeds produced have higher yield compared to those produced under flooding period.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

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