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Rodolfo, Giselle Regina; Arruda Souza, Clovis; Medeiros Coelho, Cileide Maria; Belizario, Karla Katy

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CROP PRODUCTION

Physiological quality of dual-purpose wheat seeds from plants subjected to artificial defoliation

Giselle Regina Rodolfo[1] Clovis Arruda Souza[2*] Cileide Maria Medeiros Coelho[2] Karla Katy Belizario[1]

[1]Programa de Pós-graduação em Produção Vegetal, Departamento de Agronomia, Universidade do Estado de Santa Catarina (UDESC), Lages, SC, Brasil.
[2]Departamento de Agronomia, Universidade do Estado de Santa Catarina (UDESC), 88520-000, Lages, SC, Brasil. E-mail: clovis.souza@udesc.br.
[*]Corresponding author.

ABSTRACT: *Defoliation may play a role in source-sink relationships and reduce the physiological quality of seeds. The main goal of this research was to investigate the effect of successive defoliations on physiological quality of wheat seeds in 'BRS Umbu' and 'BRS Tarumã' cultivars. Two experiments were carried out using a complete randomized design with four replications. Treatments included plants without defoliation (0), and those where 1, 2, and 3 consecutives defoliations were applied. Seeds from each treatment originated from four different lots. Data were analyzed with one-way analysis of variance and means compared by Tukey test at 5% statistical probability. Germination was not affected by defoliation, or the number of cuts, but an effect on vigor was reported.*
Key words: ***Triticum aestivum***, *cuts, germination, accelerated aging.*

Qualidade fisiológica de sementes de trigo duplo-propósito submetido a desfolhas manuais

RESUMO: *Desfolhas podem interferir na relação fonte-dreno e afetar negativamente a qualidade fisiológica das sementes. O objetivo deste trabalho foi verificar a qualidade fisiológica das sementes de trigo das cultivares 'BRS Umbu' e 'BRS Tarumã' obtidas de plantas submetidas ou não a desfolhas. Dois experimentos foram conduzidos em delineamento inteiramente casualizado com quatro repetições dos diferentes tratamentos, que consistiram em: sem corte, 1, 2 e 3 cortes, em que as sementes oriundas de cada tratamento originaram lotes distintos. Os dados foram submetidos à ANOVA e as médias comparadas pelo teste de Tukey a 5% de probabilidade. Constatou-se que a restrição de fonte não influenciou a germinação das sementes de trigo, independente do número de cortes e resultou em efeitos sobre o vigor.*
Palavras-chave: ***Triticum aestivum***, *cortes, germinação, envelhecimento acelerado.*

INTRODUCTION

Among the cold-season cereals, wheat (***Triticum aestivum*** L.) offers high yield capacity (MARINI et al., 2011). To adequately increase wheat productivity, the use of high-quality seeds, with good genetic, physiological, and sanitary characteristics, is essential (FANAN et al., 2006). Historically, about 90% of wheat production is concentrated in the southern region of Brazil (CONAB, 2016). In the period between autumn and early winter, forage shortages occur in this region (MEINERZ et al., 2012). An alternative is to use dual-purpose cereals with genotypes that may be deferred to seed production. Harvesting seeds often requires cuts or animal grazing. Cut management followed by deferral can reduce plant size, with possible effects on the yield and seeds quality (PASLAUSKI et al., 2014).

In Brazil, Law 10.711/2003 and Decree 5.153/2004 address the trade and use of seeds (BRASIL, 2004). Under these regulations, rural producers can reserve part of their own harvest for use as seeds for the next harvest. However, this legislation does not address the possibility of defoliation followed by deferral. There is little information about the effects of defoliation on germination characteristics of its seeds (HEIDARI, 2015a). In other crops such as maize, complete defoliation resulted in greater germination of seeds than that in a control group that was not defoliated (HEIDARI, 2015b). Defoliation may increases seed germination because the plants remain in a vegetative stage for a longer period of time, increasing the photosynthetic period and production

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ability (HEIDARI, 2015b). In wheat, foliar injury due defoliation levels can change assimilates source-sink balance or distribution patterns leading to crop compensation or crop damage (GONDIM et al., 2008).

Defoliation can optimize mixed systems because the production of fodder and seeds provides extra pay to the farmer as well as an opportunity to reuse seeds in the next harvest. However, stresses by defoliation can change the source-sink relationship of plants and affect the physiological quality of seeds (PEREIRA et al., 2012). This quality is evaluated by the pattern of germination, allowing for maximum germination potential and maximum performance of seed on the field (DOURADINHO et al., 2015). Tests of vigor such as accelerated aging and seedling growth can better represent the results actually obtained in the field. The accelerated aging test simulates the decay of seed through exposure to high temperature and levels of relative humidity. Lower quality seeds demonstrate reduced viability, distinguishing lots that are likely to show good performance after sowing in the field and/or during storage (MAIA et al., 2007). Determination of the protein contents can also evaluate the seed's physiological potential (BORTOLOTTO et al., 2008).

Measuring seedling growth by the length and mass of the dry matter of seedlings and offers an additional tool for determining wheat vigor (VANZOLINI et al., 2007; BELLÉ et al., 2014). Weight of a thousand seeds (WTS) can be used to compare the quality of seed lots in several species (SILVA et al., 2007; AMARO et al., 2015).

There are few published reports about seed quality in wheat from defoliated plants. However, it is important to understand the effect of defoliation on the source-sink relationships of wheat plants and on the physiological quality of seeds produced in this system. The goal of this study was to analyze the physiological quality of seeds of wheat cultivars 'BRS Umbu' and 'BRS Tarumã' obtained from plants subjected to defoliation.

MATERIALS AND METHODS

In 2014, two experiments were conducted with two wheat cultivars: 'BRS Umbu' and 'BRS Tarumã'. The study was located in Lages, Santa Catarina (27°49' SL, 50°20' W, 937m above sea level). Grazing management studies showed that plant height is a practical measure (CHAPMAN, 2012). Treatments consisted of plants without defoliations (0), and those with 1, 2, or 3 consecutive defoliations. Defoliation was performed manually with scissors when the plants reached 30cm height, leaving 15cm of stubble. The procedure was repeated as determined by the number of cuts. The intervals between cuts constituted by growth or regrowth until plants reach at least 30cm in height. For all treatments, nitrogen fertilization (50kg ha^{-1}) was applied to provide a urea source at the beginning of tillering (growth stage GS 21, according ZADOKS et al., 1974) and on the appearance of the first visible node (GS 31). This nitrogen fertilizer application was repeated after each defoliation.

When plants reached the harvest maturity stage (GS 92), seeds from each treatment were harvested with combined harvester plots (model Wintersteiger). Seeds harvested had an average moisture of 18%, and were dried in an oven with air circulation (40±2°C) to reach the required moisture content of 13%.

After drying, seeds of each treatment were homogenized for further laboratory analysis as described by the RAS (BRASIL, 2009) and stored in kraft paper packages under controlled temperature (10±3°C), with air relative humidity 40±5%, for 6 months until analysis. The following characteristics were evaluated: (A) Seed crude protein (CP) were measured by near infrared spectroscopy (Infratec Foss model 1241), using wave lengths from 570 to 1050nm. To evaluate the physiological potential of seeds, the following tests were performed at the Seed Analysis Laboratory of Universidade do Estado de Santa Catarina, in Lages, Santa Catarina: (B) Weight of a thousand seeds (WTS) were performed according to the RAS (BRASIL, 2009). Briefly, seeds were counted using an automated seed counter (Sanick ESC 2011 model) and then weighed. (C) Moisture content were determined using an oven at 105±3°C during 24h. Two replicates of 5-g seeds were used for each treatment as described previously by the RAS (BRASIL, 2009). (D) Germination test was conducted using four replications of 50 seeds, wrapped in paper roller of type "Germitest" dampened with distilled water at a ratio of 2.5 times the mass of dry paper, under a constant temperature of 20°C in a germination chamber (Mangelsdorf) during 8 days, as described by RAS (BRASIL, 2009). (E) Accelerated aging test - four repetitions (50 seeds each) were used for the seed aging test. Seeds were distributed in a single uniform layer on a stainless steel screen set in the interior of the plastic "gerbox" containing 40mL of distilled water. Boxes were capped and kept in an aging chamber for 48h with 100% relative humidity and temperature of 43°C (FANAN et al., 2006). After the aging period, germination tests were done as described above. To assess the uniformity of the assay conditions, moisture content was also evaluated after the aging period. (F) Length of seedlings and dry matter-tests were performed at germination (LS1 and DM1) and after the accelerated aging test (LS2 and DM2). Twenty seeds were sown on a longitudinal line drawn along the upper third of germination paper. Eight days later, the length of normal seedlings was measured in centimeters per seedling (root plus shoot) (BELLÉ et al., 2014). After that, seedlings were allowed to dry in an oven with air circulation (60±3°C) for weighing and dry matter analysis (NAKAGAWA, 1999).

The experiment followed a completely randomized design (CRD) with four repetitions per treatment (per cultivar for each test). Data were summarized and analyzed with analysis of variance (ANOVA), and where differences were reported, a mean comparison test was applied (Tukey HSD test, 5% probability). All analyses were performed using SAS version 9.0 software.

RESULTS AND DISCUSSIONS

Analysis of variance showed a significant effect of defoliation on the protein contents, accelerated aging, and WTS for both cultivars. Germination had a statistically significant effect in the cultivar 'BRS Tarumã' (Table 1). The quality of seeds was maintained by providing appropriate storage, maintaining the aging and the germination capacity (GOLDFARB & QUEIROGA, 2013), and consistent moisture conditions. A storage period similar to the present research was also reported in wheat (DOURADINHO et al., 2015), concluding that storing seeds under controlled conditions preserves physiological quality.

Measuring seedling length and dry matter assumes that more vigorous lots will produce seedlings with higher rates of development and gains in mass, because they are efficient in transforming tissues (AMARO et al., 2015). VANZOLINI et al. (2007) reported stratification in soybean seed vigor by measuring seedlings length. In this study, successive defoliation did not result in significant differences in mass or length of seedlings (Table 1). In an experiment with maize cultivars, HEIDARI (2015b) observed a similar outcome. MUNIZ et al. (2004) observed similar results in watermelon seeds, noting no effect of defoliation on length and dry mass of seedlings. The WTS of cultivar 'BRS Umbu' presented a tendency to decrease with the successive defoliation. For 'BRS Tarumã' cultivar, WTS decreased with the third defoliation (Table 2). A similar result was reported by SOUZA et al. (2013), in which seeds of wheat without defoliation reached a higher weight. Defoliation reduces photosynthetic area and the production of photoassimilates necessary for maintenance and seed filling (MEDEIROS & NABINGER, 2001).

After defoliation in wheat, nitrogen fertilization can increase the yield and physiological quality of seeds (PRANDO et al., 2012). In our study, protein content in 'BRS Tarumã' increased when fertilizer was added after defoliation. Increase in the protein content of seeds may be

Table 1 - Squared means of crude proteins (CP), germination (G), normal seedlings after accelerated aging test (AA), length of seedlings (LS) dry matter of the seedlings (DM) and weight of thousand seeds (WTS) of the cultivars 'BRS Umbu' and 'BRS Tarumã'. Data are representative of defoliated plants.

Source of variation	GL	CP (%)	G (%)	LS1/1 (cm)	DM1/1 (mg seedling-1)	AA (%)	LS2/2 (cm)	DM2/2 (mg seedling-1)	WTS (g)
'BRS Umbu'									
Defoliation	3	2.77**	24.00ns	0.11ns	0.47ns	330.00**	0.15ns	0.28ns	30.32**
Residual	8	0.19	24.00	0.49	0.56	15.17	1.06	0.63	4.77
Mean	-	16.28	91	17.04	8.43	56.50	16.62	8.68	29.19
CV (%)	-	2.69	5.38	4.10	8.85	6.89	6.21	9.11	7.48
'BRS Tarumã'									
Defoliation	3	1.94**	56.67**	1.85ns	2.52ns	441.00**	5.41ns	1.25ns	9.36**
Residual	8	0.003	9.17	0.57	1.92	21.00	1.86	0.49	1.20
Mean	-	18.06	90	15.42	10.02	58.25	14.69	9.34	26.66
CV (%)	-	0.31	3.36	4.89	13.81	7.87	9.28	7.50	4.12

** and *, significant at P<0.01 and P<0.05, respectively F test. ns, non-significant (P>0.05). /1 LS1 AND DM1, refers to tests performed before accelerated aging test (AA) e, /2 LS2 e DM2, refers to the tests performed after aging essay (AA).

Table 2 - Percentage of crude protein (CP), germination (G) and of normal seedlings after accelerated aging test (AA), initial moisture content (IM) and moisture after accelerated aging test (MAAA) and weight of thousand seeds (WTS) for 'BRS Umbu' and 'BRS Tarumã' cultivars, accordingly to defoliation.

Number of defoliations	CP (%)	G (%)	AA (%)	IM (%)	MAAA (%)	WTS (g)
'BRS Umbu'						
0	14.9 b	93 a	68 a	14.2 a	28.9 a	32.1 a
1	16.2 a	93 a	58 b	13.5 a	27.7 a	30.9 ab
2	16.8 a	88 a	55 b	12.9 a	28.7 a	27.5 bc
3	17.1 a	90 a	46 c	13.0 a	28.3 a	26.3 c
'BRS Tarumã'						
0	17.2 d	86 b	73 a	13.1 a	28.0 a	27.9 a
1	17.7 c	88 ab	58 b	12.5 a	28.3 a	27.8 a
2	18.2 b	91 ab	53 b	13.3 a	27.3 a	26.3 ab
3	19.1 a	94 a	49 b	12.8 a	28.2 a	24.6 b

Means followed by the same lowercase letters in each column do not differ significantly by the Tukey test ($P < 0.05$).

related to stability and increased germination capacity of the cultivar 'BRS Umbu' and 'BRS Tarumã', respectively (Table 2). CARVALHO & NAKAGAWA (1988) reported that protein content and seed vigor are positively correlated in wheat. In this study, the increase in protein explains the tolerance to loss of seed vigor by the accelerated aging test for the cultivar 'BRS Tarumã'. Increases in protein contents in cultivar 'BRS Umbu' seeds did not compensate for the detrimental effect of defoliations (Table 2).

In both cultivars, defoliation reduced vigor by accelerating the aging test (Table 2). Previous studies observed that defoliation influences seed quality, meaning that a high frequency of intense defoliation can diminish the total photoassimilates, leading to reduce the seed vigor (MEDEIROS & NABINGER, 2001). Our study is the first to demonstrate the effects of defoliation on physiological quality of seeds in dual purpose wheat. This result is of further interest because we removed 50% of plant shoot, while other researchers only removed leaves at specific stages of development (GONDIM et al., 2008; SOUZA et al., 2013; HEIDARI, 2015a; HEIDARI, 2015b). In ryegrass (PASLAUSKI et al. (2014) and in millet (SCHEFFER et al. (1985) subjected to two and four defoliations, respectively, no meaningful impacts on physiological quality of seeds due to defoliation.

Similar initial moisture content was noted in seeds for both cultivars with regard to their respective numbers of defoliation (Table 2). After accelerated aging tests, the moisture content of seeds increased two times in both cultivars and defoliation treatments (Table 2). This result demonstrates that the assays followed standard conditions and did not affect the accuracy of the results (MARCOS FILHO, 2005).

A positive correlation was reported between the protein content (CP) with all variables studied for cultivar 'BRS Umbu' ($r>0.90$) and 'BRS Tarumã', except for DM1 and LS2 ($r = 0.37$ and -0.23, respectively) (Table 3). Positive correlation between protein content, germination, and vigor measured by the accelerated aging test confirms the increase in seed protein content influences seed germination in the 'BRS Umbu' cultivar and increased the response of 'BRS Tarumã' to defoliation.

Among other functions, proteins act as reserve substances for seeds being associated with the differences in vigor (MARCOS FILHO, 2005). In this study, we noted a positive correlation between protein content and vigor measured by the accelerated aging test. For the 'BRS Umbu' cultivar, where the protein content of seeds did not increase progressively, the vigor decreased with successive defoliation. The protein content of cultivar 'BRS Tarumã' progressively increased and this result may have reduced vigor only at the first defoliation. Other positively correlated variables were the WTS and the vigor by accelerated aging test of cultivars 'BRS Umbu' and 'BRS Tarumã' ($r = 0.94$ and 0.96, respectively) (Table 3). A similar result was reported by SILVA et al. (2007), with ***Bromus auleticus***. Reduction in vigor may be related to the reduction in WTS. On the cultivar 'BRS Tarumã', WTS was clearly lower in plants subjected to three defoliations-while the vigor remained constant-

Table 3 - Pearson correlation coefficients (r) between the variables, crude protein (CP), weight of thousand seeds (WTS), germination (G), length of seedlings (LS), dry matter (DM) and vigor by accelerated aging test (AA).

	CP	WTS	G	LS1	DM1	AA	LS2	DM2
---‘BRS Umbu’---								
CP	1							
WTS	0.93**	1						
G	0.94**	0.97**	1					
LS1	0.94**	0.95**	0.94**	1				
DM1	0.95**	0.94**	0.94**	0.96**	1			
AA	0.94**	0.93**	0.94**	0.97**	0.97**	1		
LS2	0.95**	0.95**	0.95**	0.97**	0.99**	0.98**	1	
DM2	0.94**	0.92**	0.93**	0.96**	0.99**	0.98**	0.99**	1
---‘BRS Tarumã’---								
CP	1							
WTS	1.00**	1						
G	0.90**	0.90**	1					
LS1	0.93ns	0.93**	0.94**	1				
DM1	0.37ns	0.37ns	0.41ns	0.49*	1			
AA	0.96**	0.96**	0.90**	0.94**	0.32ns	1		
LS2	-0.23ns	-0.23ns	-0.05ns	-0.14ns	0.02ns	-0.24ns	1	
DM2	0.87**	0.87**	0.91**	0.97**	0.42ns	0.91**	-0.05ns	1

** and *, significant at a P<0.01 e P<0.05, respectively by test t. ns, non-significant (P>0.05). /1LS1 and DM1, refers to tests before accelerated aging test, /2LS2 and DM2, refers to tests after accelerated aging test.

than on the cultivar ‘BRS Umbu’, where the WTS reduced progressively.

In wheat, there is a relationship between the genetic potential of the cultivar and the phenotypic expression related to the source/sink manipulation of photosynthesis and partition of photoassimilates during grain filling (BARNABAS & FEHER, 2008). ALVARO et al. (2007) reported that defoliation did not alter the translocation of dry matter in plant main stem, but the sink demand was supplied by source reserves from remaining sheaths and stems. In this study, photoassimilates present in seeds during physiological maturity ranged from 75% to 92% of the carbon allocated in the plant at the pre-anthesis stage. This result is similar to ours, showing that a residual foliar area was left for the restoration of the plants after defoliation, similar to the case in the pre-anthesis stage. So, this management strategy was adopted to minimize the influence of defoliation on translocation of photoassimilates and later quality of seeds.

CONCLUSION

Results suggested that the restriction in source during tillering until booting of wheat plants does not affect the germination capacity, but does affect seed vigor. Cultivar ‘BRS Tarumã’ appears promising when the defoliation is for forage purposes and subsequent seed production.

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ERRATUM

Artigo “Physiological quality of dual-purpose wheat seeds from plants subjected to artificial defoliation” publicado no fascículo v47n1 de 2017 da Ciência Rural, nas notas de rodapé das tabelas, onde se lia:

“** and *, significant at P<0.01 and P<0.05, respectively F test. ns, non-significant (P>0.05). /1 LS1 AND DM1, refers to tests performed before accelerated aging test (AA) e, /2 LS2 e DM2, refers to the tests performed after aging essay (AA).”

“** and *, significant at a P<0.01 e P<0.05, respectively by test t. ns, non-significant (P>0.05). /1LS1 and DM1, refers to tests before accelerated aging test, /2LS2 and DM2, refers to tests after accelerated aging test.”

leia-se:

“** and *, significant at P<0.01 and P<0.05, respectively F test. ns, non-significant (P>0.05). /1 LS1 and DM1, refers to tests performed before accelerated aging test (AA) and, /2 LS2 and DM2, refers to the tests performed after aging essay (AA).”

“** and *, significant at a P<0.01 and P<0.05, respectively by test t. ns, non-significant (P>0.05). /1LS1 and DM1, refers to tests before accelerated aging test, /2LS2 and DM2, refers to tests after accelerated aging test.”

Nas referências, onde se lia:

“DOURADINHO, G.Z. et al. Potassium leachate test for the evaluation of wheat seed physiological quality. **Revista de Agricultura Neotropical**, v.2, n.3, p.18-22, 2015. Available from: <http://periodicosonline.uems.br/index.php/agrineo/article/view/266>. Accessed: Nov. 28, 2015.”

leia-se:

“DOURADINHO, G.Z. et al. Potassium leaching test for the evaluation of wheat seed physiological quality. **Revista de Agricultura Neotropical**, v.2, n.3, p.18-22, 2015. Available from: <http://periodicosonline.uems.br/index.php/agrineo/article/view/266>. Accessed: Nov. 28, 2015.”

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