https://doi.org/10.15446/ing.investig.v42n2.89116

Growth and Physiological Performance of Barley Plants Produced under Nitrogen Management

Crecimiento y rendimiento fisiológico de plantas de cebada producidas bajo manejo de nitrógeno

Bruno Oliveira Novais Araújo[1], Felipe Santos Zulli[2], Eduardo Goncalvez Borges[3], Manoela Andrade Monteiro[4], Jessica Mengue Rolim[5], Leticia Barao Medeiros[6], Angelita Celente Martins[7], Tiago Pedó[8], and Tiago Zanatta Aumonde[9]

ABSTRACT

This work aimed to evaluate the effect of nitrogen dose management on the growth responses and physiological performance of barley seeds. Two barley cultivars (BRS Brau and BRS Cauê) and four nitrogen doses were used. The experimental design consisted of randomized blocks in a 2 X 4 factorial scheme (cultivars BRS Brau and BRS Cauê x nitrogen doses 120, 150, 180, and 210 kg ha^{-1}). Successive collections of primary data were performed every fourteen days for growth analysis. The analyzed variables were total dry matter, dry matter production and relative growth rate, assimilated partition, and seed electrical conductivity. Increasing nitrogen doses caused a temporal-quantitative difference in growth, partition, and the accelerated aging test of barley seeds. The 150 kg ha^{-1} N dose resulted in total dry matter over time (Wt) superiority for both evaluated cultivars. The variable dry matter production rate achieved an increase with the 150 kg ha^{-1} N dose at 70 days after emergence (DAE) for BRS Brau and at 56 DAE for BRS Cauê supporting Wt. The 180 and 150 kg ha^{-1} N doses increased the relative growth rate for BRS Brau and BRS Cauê.

Keywords: cereal, fertilizer, *Hordeum vulgare*

RESUMEN

Este trabajo tuvo como objetivo evaluar el efecto del manejo de las dosis de nitrógeno en las respuestas de crecimiento y el rendimiento fisiológico de las semillas de cebada. Se utilizaron dos cultivares de cebada (BRS Brau and BRS Cauê) y cuatro dosis de nitrógeno. El diseño experimental consistió en bloques al azar en un esquema factorial 2 X 4 (cultivares BRS Brau y BRS Cauê x dosis de nitrógeno 120, 150, 180 y 210 kg ha^{-1}). Se realizaron recolecciones sucesivas de datos primarios cada catorce días para el análisis de crecimiento. Las variables analizadas fueron materia seca total, producción de materia seca y tasa de crecimiento relativa, partición asimilada y conductividad eléctrica de las semillas. El aumento de las dosis de nitrógeno causa una diferencia cuantitativa-temporal en el crecimiento, partición y la prueba de envejecimiento acelerado de las semillas de cebada. La dosis de 150 kg ha^{-1} N resultó en una superioridad total de la materia seca en el tiempo (Wt) para ambos cultivares evaluados. La tasa variable de producción de materia seca logró un aumento para la dosis de 150 kg ha^{-1} N a los 70 días después de la germinación (DAE) para BRS Brau y a 56 DAE para BRS Cauê apoyando Wt. Las dosis de 180 y 150 kg ha^{-1} N aumentaron la tasa de crecimiento relativo para BRS Brau y BRS Cauê.

Palabras clave: cereal, fertilizante, *Hordeum vulgare*

Received: July 13th 2020
Accepted: August 6th 2021

[1] Agronomist Engineer, Department of Crop Protection, Federal University of Pelotas – Pelotas, Rio Grande do Sul, Brazil. Affiliation: Master's student in the Crop Protection Graduate Program, Federal University of Pelotas, Pelotas, RS CEP 96160-000, Brazil. Email: bruno-tec@outlook.com

[2] Agronomy student, Federal University of Pelotas – Pelotas, Rio Grande do Sul, Brazil. Email: filipyz@hotmail.com

[3] Agronomist Engineer. Federal University of Pelotas – Pelotas, Rio Grande do Sul, Brazil. Email: eduardogborges@gmail.com

[4] Agronomist Engineer, Ph.D. in Science, Department of Phytotechnics, Federal University of Pelotas – Pelotas, Rio Grande do Sul, Brazil. Email: manu_agro@hotmail.com

[5] Forest engineer, M.Sc. in Forest engineer, Federal University of Santa Maria, RS, Brazil. Affiliation: Doctoral Student in Seed Science and Technology, Federal University of Pelotas. Pelotas, Rio Grande do Sul, Brazil. Email: eng.jessicarolim@gmail.com

[6] Agronomist Engineer, M.Sc. in Agrobiology, Federal University of Santa Maria, RS, Brazil. RS, Brazil. Affiliation: Doctoral Student in Seed Science and Technology, Federal University of Pelotas. Pelotas, Rio Grande do Sul, Brazil. Email: lele-medeiros@hotmail.com

[7] Biological Sciences, M.Sc., and Ph.D. in Plant Physiology. Federal University of Pelotas – Pelotas, Rio Grande do Sul, Brazil. Email: angel-celente@hotmail.com

[8] Agronomist Engineer, Ph.D. in Science, Federal University of Pelotas – Pelotas, Rio Grande do Sul, Brazil. Affiliation: Associate Professor, Federal University of Pelotas (Brazil). Rio Grande do Sul, Brazil. Email: tiago.pedo@gmail.com

Introduction

Barley (*Hordeum vulgare* L.), a member of the *Poaceae* family, is grown in cold seasons. In the southern region of Brazil, the ideal time for sowing is between May and June, which is appropriate for winter growing (Texeira Filho *et al.*, 2008). The zoning for this cultivation aims to escape the times of frost occurrence when the crop is established and begins to grow, as well as the rainfall during the grain harvest period.

[9] Agronomist Engineer, Ph.D. in Science, Federal University of Pelotas – Pelotas, Rio Grande do Sul, Brazil. Affiliation: Associate Professor, Federal University of Pelotas (Brazil). Rio Grande do Sul, Brazil. Email: tiago.aumonde@gmail.com

How to cite: Novais, B. O., Santos, F., Goncalvez, E., Monteiro, M., Mengue, J., Barao, L., Celente, A., Pedó, T. and Zanatta, T. (2022). Growth and Physiological Performance of Barley Plants Produced under Nitrogen Management. *Ingeniería e Investigación, 42*(2), e89116. https://doi.org/10.15446/ing.investig.v42n2.89116

The southern region of Brazil is the main producer of barley in the country, with beer production and animal feed being the largest end consumers of this production (De Mori and Minella, 2012). In the 2018 harvest, the area proposed for the cultivation of barley was just over 111 thousand ha, which represented a decrease of 3,2% compared to the previous year. In Rio Grande do Sul, there was a similar reduction in the area intended for grain growth - around 2,5% - decreasing from 57 thousand to 55,6 thousand ha.

The productivity achieved in Brazil during the 2019 harvest was 3 557 kg ha^{-1}: an increase of 12,6% compared to the previous year, which was 3 159 kg ha^{-1}. The crops of Rio Grande do Sul, however, reached the average yield of 2 370 kg ha^{-1}, also showing a 25,4% drop compared to 2018.

Although there was no change in the cultivated area in the country, national production decreased by 12,3% compared to the 2018 harvest. Rio Grande do Sul is the second largest producer in the country, with a production of 134,4 thousand tons in 2019, even with a 25,2% drop in production vs. the 2018 harvest. Paraná, which remained the largest barley producer in Brazil, showed a 3,1% reduction, which is equivalent to the production of 237,6 thousand tons (CONAB, 2020).

Nitrogen is considered essential for plants. In soil under adequate aeration conditions, this nutrient is absorbed as nitrate by the root system, and it can be accumulated in the cell vacuoles or transported, thus serving as a component of amino acids, proteins, and nucleic acids (Taiz and Zeiger, 2017).

The amount of nitrogen provided to plants, among other factors, depends on the nutritional requirement of the crop. There is a wide range of nitrogen sources on the market such as urea, Chile saltpeter ($NaNO_3$), Bengal saltpeter (KNO_3), ammonium sulfate ($(NH_4)_2SO_4$), cattle manure (1,7% N), and poultry litter (3,0% N). However, among the available nitrogen sources, the most widely employed in agriculture is urea since it is easily acquired and cost-effective.

The technical recommendations for fertilization and acidity correction in Brazilian soils aim to improve grain yield. However, the best nutritional condition or management for a good performance is not always equivalent to the one that prioritizes seed quality. Several factors affect physiological quality, including maturation, phytosanitary condition, and nutritional availability in the development of the embryonic axis, as well as the nutritional and the stressful conditions under which the seed was formed, which may change its weight and size, as evaluated by Soares *et al*. (2008).

Growth analysis allows quantifying vegetable carbon allocation in its variability along the crop cycle. In addition to being considered low-cost and accurate, this method can be applied throughout the growth and development of the species, and it is used to evaluate differences in response to management or environmental variations (Koch *et al*., 2017).

On the other hand, seed quality can be gauged by vigor, so that the immediate and uniform emergence of seedlings will favor early crop establishment. In this sense, the expression of seed vigor can be determined by means of several tests such as electrical conductivity, field seedling emergence, first germination count, and aging tests (Silva *et al*., 2014).

This work aimed to evaluate the effect of nitrogen doses on the growth responses and physiological performance of barley seeds.

Materials and methods

The experiment was performed in a didactic and experimental area at the Federal University of Pelotas (UFPel), Department of Phytotechnics, PPG in Seed Science and Technology (31 ° 52 'S; 52 ° 21' W). The data of maximum and minimum temperature (°C), solar radiation (cal cm^{-2} day^{-1}), rainfall (mm), and relative humidity (%) were obtained from a climate report from the Pelotas agroclimatological station (Figure 1), located near an UFPel campus.

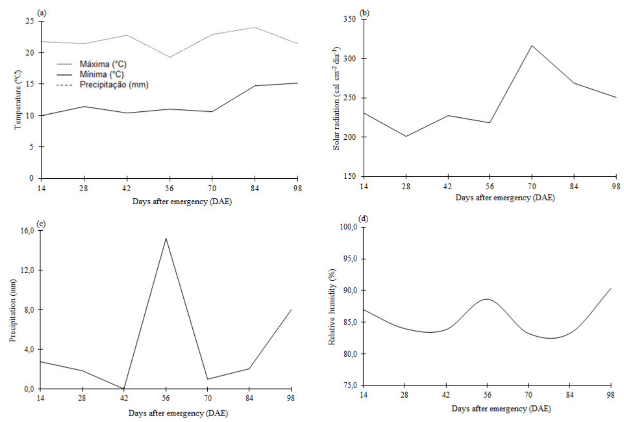

Figure 1. Maximum and minimum temperature (°C), solar radiation (cal cm-2 day-1), precipitation (mm), and relative humidity (%) data from the Pelotas agroclimatological station
Source. Authors

The seeds of two barley cultivars (BRS Cauê and BRS Brau) indicated for the states of Paraná, Santa Catarina, and Rio Grande do Sul were used. Sowing was carried out in a soil classified as *Solodic Eutrophic Haplic Planosol* (Streck *et al*., 2008).

Soil correction was performed according to the requirements determined in the soil analysis (Table 1), as well as the recommendations of the fertilization and liming manual of the states of Rio Grande do Sul and Santa Catarina (CQFS, 2016) for a productivity of four tons per ha.

Table 1. Chemical analysis of the soil used as a basis for the correction of acidity and fertility for the cultivation of barley (Pelotas, RS)

O.M.	pH	Clay	P	K	Ca	Mg	Al	H+Al	AEC	V	Ind.
%	H_2O	%	mg dm^{-3}		cmol dm^{-3}					%	SMP
2,07	4,8	14	21,5	27	3,3	1,1	0,3	6,2	4,9	42	5,7

Source: Authors

Regarding soil fertility correction, 60 kg ha^{-1} of phosphorus and potassium were required, and they were obtained using triple super phosphate (41% P_2O_5) and potassium chloride (58% K_2O) as sources. Nitrogen fertilization required 120 kg ha^{-1} as a control treatment, which was divided into two applications – sowing and tillering – sixteen days after emergence (DAE) with respective doses of 20 kg ha^{-1} and 100 kg ha^{-1}, as well as urea being the nitrogen source (45% N).

The experiment consisted of a randomized block design in a 2 X 4 factorial scheme (two cultivars and four nitrogen doses) and four replications, with five lines spaced 0,17 m and 1,80 m in length. The corrected population density was 250 plants per m^2 as recommended (Embrapa, 2007).

The treatments consisted of nitrogen doses comprised by T1 100% (control), which received the 120 kg ha^{-1} dose; T2 125% (150 kg ha^{-1}); T3 150% (180 kg ha^{-1}); and T4 175% (210 kg ha^{-1}). For growth evaluations, samples were collected throughout the crop cycle at regular intervals of fourteen days after emergence. In each collection, the plants were separated into different structures (roots, stalks, leaves, and ears). To determine the leaf area (A_f) the Liquor LI-3100 area meter was used, and the results were expressed in square meters (m²). Subsequently, the plant components were placed separately in brown paper envelopes and, to obtain the dry matter, the structures were taken to the greenhouse with forced ventilation at a temperature of 70° ± 2°C until constant mass was achieved.

The total dry matter over time (W_t) data were adjusted using the simple logistic equation: $W_t = W_m/(l + A_e^{-Bt})$, where W_m is the asymptotic estimate of maximum growth; "A" and "B" are adjustment constants; "e" is the natural basis of the neperian logarithm; and "t" is the time in days after emergence (Richards, 1969). The primary dry matter data of leaves (W_f), roots (W_r), stalks (W_c), and ears (W_{esp}) were adjusted using orthogonal polynomials (Richards, 1969). The instantaneous dry matter production rate values (C_t) were obtained by derivative from the adjusted total dry matter equations (W_t). The equation $R_w = l/W_t \cdot d_w/d_t$ was used to determine the instantaneous values of the relative growth rate (R_w) (Radford, 1967).

The dry matter partition between the different organs was determined from the total dry mass allocated in each structure in relation to the total dry matter, and the results were expressed in percentage.

Electrical conductivity was determined from four samples containing four subsamples of 25 seeds for each treatment. The seeds were mass measured after being placed in polyethylene cups containing 80 mL of deionized water, which was kept in a *Biochemical Oxygen Demand* (BOD) type germinator at a temperature of 20°C with a 12-hour photoperiod. The electrical conductivity was determined after 3, 6, and 24 h of imbibition by means of a digital conductivity meter. The results were expressed as μS cm^{-1} g^{-1} seeds (Ollson *et al*., 2010).

Primary growth data were subjected to an analysis of variance at 5% probability, and the total dry matter was analyzed by simple logistic equation (Lopes and Lima 2015). Assimilated partition data were converted to percentage of dry matter allocated to each evaluated structure, whereas those related to germination and vigor were represented by orthogonal polynomials when significant at 5% probability.

Results and discussion

There was a significant difference for the primary values of leaf area, leaf, stalks, roots, and ear dry matter (Table 2). Total dry matter values (W_t) were adjusted for the simple logistic tendency for both cultivars submitted to nitrogen doses (Figure 2).

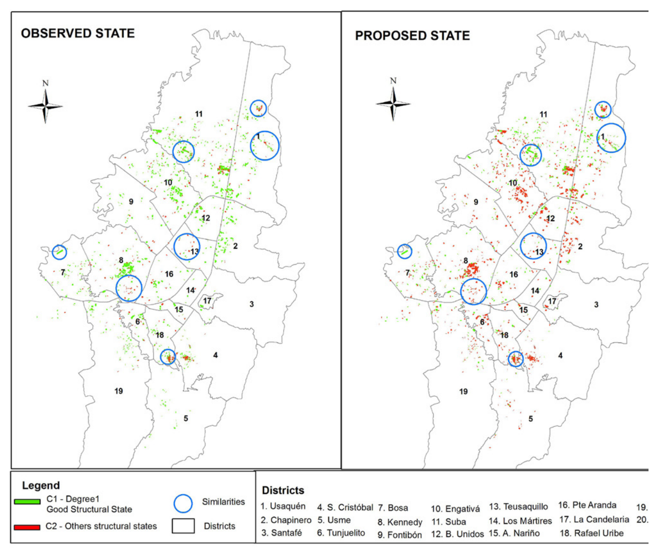

Figure 2. Total dry matter (a, b), dry matter production rate (c, d), and relative growth rate (e, f) in two barley cultivars (BRS Brau and BRS Cauê) in Pelotas, RS
Source: Authors

W_t was low at the beginning of the cycle until about 28 DAE (days after emergence), with a subsequent sharp increase in dry mass production. For cultivar BRS Brau, 82 days after nitrogen application, there was an increase of 8,66% and a decrease of 11,37 and 6,37% in the production of T2-weighted matter (150 kg ha^{-1} N), T4 (210 kg ha^{-1} N), and T3 (180 kg ha^{-1} N) in relation to the control dose, respectively.

For cultivar BRS Cauê, 82 days after nitrogen application, there was an increase of 0,88% and a decrease of 18,82 and 11,50% in dry matter yield at doses of T2 (150 kg ha^{-1} N), T3 (180 kg ha^{-1} N), and T4 (210 kg ha^{-1} N) in relation to the control dose, respectively. At the end of the development cycle of cultivars BRS Brau and BRS Cauê, plants under T2 application (150 kg ha^{-1} N) reached a higher total dry matter production.

Table 2. Summary analysis of variance with mean squares for leaf dry matter (W_f), stem (W_c), root (W_r), and ear (W_{esp}) data of barley cultivars produced under application of nitrogen doses (Pelotas, RS)

Factor	DF	MS W_f	MS W_c	MS W_r	MS W_{esp}
CV	1	2 032,6392*	6 396,1151*	5 731,8153*	7 212,0514*
Times	6	1 3801,025	7 7588,403	14 083,167	351 514,63
Doses	3	572,86774^{ns}	591,31676^{ns}	118,60777^{ns}	568,91259^{ns}
CV X Times	6	1 156,7783*	368,70568*	470,46378^{ns}	5 993,0143*
Doses X Times	18	883,0618*	920,46653^{ns}	453,6561*	1 195,0103^{ns}
CV X Doses	3	706,54951^{ns}	671,5948^{ns}	340,72553^{ns}	3 327,483^{ns}
CV X Doses X Times	18	377,22714^{ns}	671,5948*	324,933^{ns}	2 477,5966^{ns}
Total	223				
Average		37,91	42	27	63
CV(%)		43,64	G	58	61

Note: (*) significance level 5%; (^{ns}) not significant
Source: Authors

A lower initial plant growth is normal during development due to the low leaf area and low root volume. At this stage, the plants have a low assimilate production capacity, reduced respiratory demand, and low water and nutrient absorption, which limits their growth. Koch *et al.* (2017) observed a similar behavior while studying the response of wheat plants with nitrogen fertilization and growth regulator application.

The dry matter production rates (C_t) were low up to about 28 DAE (Figure 2c, d), which corroborates the total dry matter data for the same period. The maximum dry matter yield rates for both cultivars were obtained at approximately 56 DAE.

For cultivar BRS Brau, the maximum C_t was observed at 56 DAE for T3 (180 kg ha^{-1} N), with an increase of 31,7%, and at 70 DAE for T2 (150 kg ha^{-1} N) and T4 (210 kg ha^{-1} N), which represented an increase of 9,97% and a decrease of 1,15%, respectively, according to the control dose. For the cultivar BRS Cauê, at 56 DAE, the T2-influenced plants (150 kg ha^{-1} N) increased by 46,6%, and, at 70 DAE, the plants under the influence of T3 (180 kg ha^{-1} N) and T4 (210 kg ha^{-1} N) showed a decrease of 19,8 and 16,8%, for C_t in relation to the control dose.

The highest doses of nitrogen available in the soil did not have a direct relation to the maximum rate of dry matter production but obtained a temporal difference for cultivar BRS Brau. Cultivar BRS Cauê also presented variation according to the dose used. Thus, the adequate amount of nitrogen available to the plants could provide greater assimilation and conversion of this mineral into amino acids and proteins, which are related to the growth and development of the crop (Malavolta, 2006), that is, according to the capacity of the cultivar used.

The relative growth rate (R_w) for both cultivars showed maximum values at the beginning of development (14 DAE), with a subsequent systematic decrease until the end of the plant cycle (Figures 2d, e). It was observed that, at 14 DAE, cultivar BRS Brau obtained a difference in growth rate in relation to the different doses, in which treatments T2 (150 kg ha^{-1} N), T3 (180 kg ha^{-1} N), and T4 (210 kg ha^{-1} N) resulted in an increase in R_w in the order of 17,9, 55,7, and 27,4% in relation to the control.

Cultivar BRS Cauê, evaluated at 14 DAE, showed a difference in R_w values for treatments: T2 (150 kg ha^{-1} N) resulted in an increase of 76,2%; whereas the T3 (180 kg ha^{-1} N) and T4 (210 kg ha^{-1} N) treatments reported decreases of 2 and 6,3% in relation to the control.

When they are young, crop plants have high an assimilation capacity via photosynthesis. This kind of performance is partly due to the high amount of young tissues with high photosynthetic rate that favor relative growth (Aumonde *et al.*, 2013). The gradual decrease of R_w over the course of the plant cycle arises from the progressive increase of non-photosynthetic tissues and increased respiration of older tissues (Pedó *et al.*, 2015). This may also be caused by self-shading and loss in assimilate production efficiency (Aumonde *et al.*, 2013).

Dry matter partitioning of barley plants under application of nitrogen doses resulted in quantitative differences in their different organs in both cultivars. At 28 DAE, plants from treatments T4 (210 kg ha^{-1} N) and T2 (150 kg ha^{-1} N) in cultivar BRS Brau presented a higher W_f accumulation than the control treatment: approximately 4,57 and 0,63%, respectively. T3 (180 kg ha^{-1} N) obtained a reduction of 3,38% compared to T1 (control). When W_c was analyzed, it could be observed that treatments T2 (150 kg ha^{-1} N), T4 (210 kg ha^{-1} N), and T3 (180 kg ha^{-1} N) presented superiority of 118,10, 79,31, and 31,46% compared to T1. The results of the variable W_r showed that T3 (180 kg ha^{-1} N) increased by 3,71%, while T2 (150 kg ha^{-1} N) and T4 (210 kg ha^{-1} N) decreased in the order of 12,6 and 29,65% in relation to T1 (Figure 3 a, c, e, g).

When the cultivar Cauê was analyzed for the variable W_f, a similar behavior at 28 DAE was observed, where T2 (150 kg ha^{-1} N) and T4 (210 kg ha^{-1} N) had higher increases of (9,23 and 4,26%). Yet, T3 (180 kg ha^{-1} N) obtained a 7% decrease in relation to T1. For W_c, however, T3 (180 kg ha^{-1} N) was the one with a superiority of 21,52%, whereas T2 (150 kg ha^{-1} N) and T4 (210 kg ha^{-1} N) presented inferior results: 23,62 and 14,82% in relation to T1. The same occurred while observing W_r, in which T3 (180 kg ha^{-1} N) presented a 17,61% superiority to T1 (control), whereas T2 (150 kg ha^{-1} N) and T4 (210 kg ha^{-1} N) showed a reduction of 35,04 and 10,81% when compared to T1 (control) (Figure 3 a, c, e, g).

Adjustments in preferential metabolic drainage occur during the development of the culture, which will allocate products from photosynthesis. In the early stages of growth, leaf and root accumulation is preferred, and, later, the allocation to the stalks, reproductive structures, and ears. Thus, the direction of assimilates from source leaves to seeds occurs in greater quantity and intensity according to the preference of the drain (Lopes *et al*., 2011).

There was no significant difference when evaluating the electrical conductivity in seeds during the 3 h soaking period. However, for 24 h, it could be observed that the maximum flexion point occurred at 120kg ha^{-1} N (T1) for cultivar BRS Brau, while, for the cultivar BRS Cauê, the maximum point occurred with the 150 kg ha^{-1} N dose (T2) (Figure 4b). Bazzo *et al*. (2018), while studying nitrogen doses on the physiological quality of wheat seeds, observed that increasing the dose results in changes in physiological quality.

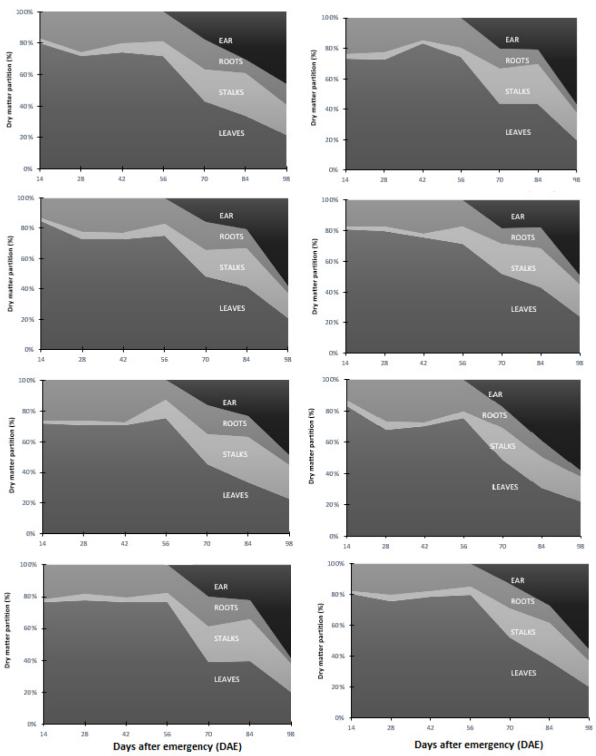

Figure 3. Dry matter partitioning of barley plants under application of nitrogen doses (control, 150, 180, and 210 kg ha^{-1} N) in two barley cultivars (BRS Brau and BRS Cauê) (Pelotas, RS)
Source: Authors

Adjustments in preferential metabolic drainage occur during the development of the culture, which will allocate products from photosynthesis. In the early stages of growth, leaf and root accumulation is preferred, and, later, the allocation to the stalks, reproductive structures, and ears. Thus, the direction of assimilates from source leaves to seeds occurs in greater quantity and intensity according to the preference of the drain (Lopes *et al*., 2011).

There was no significant difference when evaluating the electrical conductivity in seeds during the 3 h soaking period. However, for 24 h, it could be observed that the maximum flexion point occurred at 120kg ha^{-1} N (T1) for cultivar BRS Brau, while, for the cultivar BRS Cauê, the maximum point occurred with the 150 kg ha^{-1} N dose (T2) (Figure 4b). Bazzo *et al*. (2018), while studying nitrogen doses on the physiological quality of wheat seeds, observed that increasing the dose results in changes in physiological quality.

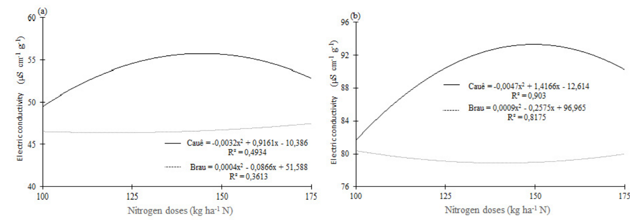

Figure 4. Results of the electrical conductivity analysis of the seeds after a 3- and 24-hour imbibition period (a, b), respectively (Pelotas, RS)
Source: Authors

It should be pointed out that the response to nitrogen fertilization might be due to the influence of the cultivar (genetic factors), the nitrogen source (availability to the crop) and the type of soil (factors linked to adsorption). It is possible that some cultivars in certain soil types and under different nitrogen sources direct most of the nitrogen to seeds and favor aspects related to their physiology in terms of vigor.

Conclusions

Increasing nitrogen doses causes temporal and quantitative difference in growth, partitioning, and accelerated aging test of barley seeds.

The 150 kg ha^{-1} N dose resulted in a superiority of total dry matter over time (W_t) for both evaluated cultivars.

The variable dry matter production rate (C_t) increased by 31,7% for the 150 kg ha^{-1} N dose at 70 DAE for BRS Brau, whereas BRS Cauê showed an increase of 46,6% at 56 DAE, thus corroborating W_t.

The 180 kg ha^{-1} N and 150 kg ha^{-1} N doses resulted in higher relative growth rates (R_w) for both BRS Brau and BRS Cauê.

Higher-than-recommended nitrogen doses did not change the harvest index in barley plants. However, depending on the dose, it changed the assimilated carbon partition.

References

Aumonde, T. Z., Pedó, T., Martinazzo, E. G., Moraes, D. M., Villela, F. A., and Lopes, N. F. (2013). Análise de crescimento e partição de assimilados em plantas de maria-pretinha submetidas a níveis de sombreamento. *Planta Daninha*, *31*(1), 99-108. https://doi.org/10.1590/S0100-83582013000100011

Bazzo, J. H. B., da Costa, D. S., Barbizan, T., Barbosa, A. P., de Oliveira, E. C., and Zucareli, C. (2018). Molybdenum application associated with nitrogen fertilization on yield and physiological potential of wheat seeds. *Semina:-Ciencias Agrarias*, *39*(1), 67-76. https://doi.org/10.5433/1679-0359.2018v39n1p67

CONAB (2019). Safra 2019/20: Décimo segundo levantamento. *Acompanhamento da Safra Brasileira de Grãos 2019/2020*, *7*, 1-114. https://www.conab.gov.br/info-agro/safras/graos/boletim-da-safra-de-graos?start=20

De Mori, C. and Minella, E. (2012). *Aspectos econômicos e conjunturais da cultura da cevada. - Portal Embrapa*. https://www.embrapa.br/busca-de-publicacoes/-/publicacao/969145/aspectos-economicos-e-conjunturais-da-cultura-da-aveia%0Ahttp://www.cnpt.embrapa.br/biblio/do/p_do139.htm

Embrapa (2007). *Indicações técnicas para produção de cevada cervejeira nas safras 2007 e 2008*. Embrapa. https://www.embrapa.br/busca-de-publicacoes/-/publicacao/821534/indicacoes-tecnicas-para-a-producao-de-cevada-cervejeira--nas-safras-2007-e-2008

Koch, F., Aisenberg, G. R., Monteiro, M. A., Pedó, T., Zimmer, P. D., Villela, F. A., and Aumonde, T. Z. (2017). Growth of wheat plants submitted to theapplication of the growth regulator trinexapac-ethyl and vigor of theproduced seeds. *Agrociencia Uruguay, 21*(1), e167. https://doi.org/10.31285/agro.21.1.4

Lopes, N. F. and Lima, M. da G. de S. (2015). *Fisiologia da produção*. UFV.

Lopes, W. A. R., Negreiros, M. Z., Dombroski, J. L. D., Rodrigues, G. S. O., Soares, A. M., and Araújo, A. P. (2011). Análise do crescimento de tomate 'SM-16' cultivado sob diferentes coberturas de solo. *Horticultura Brasileira, 29*(4), 554-561. https://doi.org/10.1590/S0102-05362011000400019

Malavolta, E. (2006). *Manual de nutrição mineral de plantas*. Editora Agronômica Ceres.

Ohlson, O. C., Krzyzanowski, F. C., Caieiro, J. T., Panobianco, M. (2010). Teste de envelhecimento acelerado em sementes de trigo. *Revista Brasileira de Sementes, 32*(4). https://doi.org/10.1590/S0101-31222010000400013

Pedó, T., Martinazzo, E. G., Aumonde, T. Z., and Villela, F. A. (2015). Plant growth analysis and seed vigor expression: Effects of soil waterlogging during rye plant development. *Acta Botanica Brasilica*, *29*(1), 1-7. https://doi.org/10.1590/0102-33062014abb3574

Radford, P. J. (1967). Growth analysis formulae - their use and abuse 1. *Crop Science*, *7*(3), 171-175. https://doi.org/10.2135/cropsci1967.0011183x000700030001x

Richards, F. J. (1969). The quantitative analysis of growth. In: F. C. Stewward (Ed), *Plant physiology* (pp. 3-76). Academic Press. http://dx.doi.org/10.4236/as.2011.23026

Silva, V. N., Zambiasi, C. N., Tillmann, M. A. A., Menezes, N. L., and Villela, F. A. (2014). Electrical conductivity test with parts of bean seeds. *Revista de Ciências Agrárias, 37*, 206-213. https://www.cabdirect.org/cabdirect/FullTextPDF/2014/20143319097.pdf

Soares, M. M., Oliveira, G. L., Soriano, P. E., Sekita, M. C., and sediyama, T. (2013). Performance of soybean plants as function of seed size: II. Nutritional stress. *Journal of Seed Science, 35*(4), 419-427. https://doi.org/10.1590/S2317-15372013000400002

Streck, E. V., Kämpf, N., and Dalmolin, R. S. D. (2008). *Solos do Rio Grande do Sul* (2nd ed.). EMATER/RS; UFRGS.

Taiz, L., Zeiger, E., Moller, I. M., and Murphy, A. (2017). *Fisiologia e desenvolvimento vegetal* (vol. 6). Artmed.

Texeira Filho, M. C. M., Buzetti, S., Alvarez, R. de C. F., Freitas, J. G. de, Arf, O., and Sá, M. E. de. (2008). Desempenho agronômico de cultivares de trigo em resposta a população de plantas e a adubação nitrogenada. *Científica*, *36*(2), 97-106. https://doi.org/10.15361/1984-5529.2008v36n2p97%20-%20106