Physiological performance of wheat seeds coated with micronutrients[1]

Lizandro Ciciliano Tavares[2]*, Cassyo de Araújo Rufino[2], André Pich Brunes[2], Felipe Freire Friedrich[2], Antonio Carlos Souza Albuquerque Barros[2], Francisco Amaral Villela[2]

ABSTRACT - The objective of this study was to evaluate the physiological performance of wheat seeds coated with micronutrients. The treatments were combinations of two products based on micronutrients, product "A": 780.0 g.L^{-1} of zinc and product "B": 182.4, 7.6 and 45.6 g.L^{-1} of zinc, boron and molybdenum, respectively, with five dosages of the products: 0, 1, 2, 3 and 4 mL. kg^{-1} seed, totaling 10 treatments with four replications. Physiological quality of the treated seed was evaluated from germination and vigor tests and the early plant growth from determinations of shoot dry weight, plant height and leaf area at 10, 20 and 30 days after emergence (DAE), as well as the rate of crop growth, relative and net assimilation. Seed yield and physiological quality were determined after harvest. It was concluded that coating wheat seeds with the product "A" , based on zinc and "B", consisting of zinc, boron and molybdenum, respectively, up to a dosage of 4 mL.kg^{-1} seed, did not adversely affect the physiological quality of the treated seeds or those produced. Both products tested resulted in increases in leaf area, plant height and shoot dry weight up to 30 DAE, as well as a higher seed yield.

Index terms: *Triticum aestivum* L., early growth, physiological quality, yield.

Desempenho fisiológico de sementes de trigo recobertas com micronutrientes

RESUMO - Objetivou-se avaliar neste trabalho o desempenho fisiológico de sementes de trigo recobertas com micronutrientes. Os tratamentos consistiram da combinação de dois produtos a base de micronutrientes, produto "A": 780.0 g.L^{-1} de zinco e o produto "B": 182,4; 7,6 e 45,6 g.L^{-1} de zinco, boro e molibdênio, respectivamente, e cinco doses dos produtos: 0, 1, 2, 3 e 4 mL.kg^{-1} de semente, totalizando 10 tratamentos, com quatro repetições. A qualidade fisiológica das sementes tratadas foi avaliada por testes de germinação e vigor e o crescimento inicial das plantas foi avaliado pela massa seca da parte aérea, altura de planta e área foliar aos 10, 20 e 30 dias, após a emergência (DAE), além da taxa de crescimento da cultura, relativo e assimilatória líquida. Após a colheita avaliaram-se o rendimento e a qualidade fisiológica das sementes. Conclui-se que o recobrimento de sementes de trigo com o produto "A" (zinco) e "B" (zinco, boro e molibdênio), até a dose de 4 mL.kg^{-1} de semente, não prejudicam a qualidade fisiológica das sementes tratadas e produzidas. Os produtos testados promovem maior área foliar, altura de planta e massa seca da parte aérea até os 30 DAE, bem como proporcionaram maior rendimento de sementes.

Termos para indexação: *Triticum aestivum* L., crescimento inicial, qualidade fisiológica, rendimento de sementes.

Introduction

Wheat (*Triticum aestivum* L.) is a winter crop commonly grown in South Brazil and has contributed significantly to Brazil's economy. However, its productivity varies from year to year and region to region, due to various factors, including nutritional deficiency, diseases, pests and soil fertility. Brazil plants around 2.5 mm ha of wheat with a productivity of about 2,600 kg.ha^{-1} and a total production above 6 million tons (CONAB, 2010). The incorporation of new technologies has resulted in significant productivity increases, with the most recent contributions being from the seed industry.

Seed treatment has been increasing due to its advantages (Goulart and Melo Filho, 2002) and Delouche (2005) has stated that coating is among the most interesting and beneficial treatments for improving seed performance. Micronutrients are chemical elements essential for plant growth and are necessary in small quantities (Mortvedt, 2001) and although their participation is small, the absence of any one of them can result in significant reductions in productivity.

Zinc and boron are the micronutrients which are most deficient in Brazilian soils (Ribeiro et al., 1994) and it is

[1]Submitted on 11/21/2011. Accepted for publication on 05/02/2012.
[2]Departamento de Fitotecnia, Universidade Federal de Pelotas, Caixa Postal 354, 96001-970 - Capão do Leão, RS, Brasil.
*Corresponding author <lizandrocicilianotavares@yahoo.com.br>

estimated that around 170 mm hectares of soils with cerrado vegetation in Central Brazil are deficient in zinc and about 108 mm hectares deficient in boron (Lopes, 1984). Deficiencies were also found in other Brazilian states (Ribeiro and Santos, 1996) and this problem may be corrected with seed treatment based on the principle that the seed reserves are an important source of zinc for preventing the development of initial symptoms of deficiency in plants.

The application of zinc on seeds acts at germination and initial seedling growth, besides favoring the physical quality of the seeds produced and resulting in a greater uniformity in distribution , economy in transport costs and the application and rationalization in the use of non-renewable reserves (Santos, 1981). The basis for the efficiency of zinc in seed treatment is its translocation to the whole plant and zinc reserves become important in stopping the appearance of the first symptoms of deficiency (Ribeiro and Santos, 1996). Zinc activity is effective for certain important processes in the physiological and nutritional homeostasis of the plant, acting as an activator, or structural component, of enzymes, by participating in C_4 plant photosynthesis with the pyruvic carboxylase enzyme (Orioli Júnior et al., 2008). It is necessary to produce tryptophan, the amino acid precursor of indoleacetic acid, a plant growth hormone involved in nitrogen metabolism and necessary for maintaining membrane integrity (Malavolta, 2006).

Nutrients have a relevant role during seed formation, development and maturation, principally in the constitution of membranes and the accumulation of lipids, carbohydrates and proteins (Sá, 1994). The application of zinc to seeds occurs in the early stages in Brazil and, therefore, the application of zinc on wheat seeds may be promising. Since the quantities of micronutrients needed by wheat are low, this makes its uniform application in the field difficult and favors a seed application, which is more uniform, with the nutrients being closer to seedling roots and resulting in higher absorption

The objective of this study was to evaluate the physiological performance of wheat seeds coated with micronutrients.

Material and Methods

This study was done with wheat seeds of the BRS Guamirim cultivar during the 2010 crop season in the Seed Analysis Teaching Laboratory (LDAS) and in a greenhouse of the Eliseu Maciel Agronomy Department of the Federal University of Pelotas, Capão do Leão – Rio Grande do Sul State.

The treatments consisted of a combination of two products based on micronutrients, in a 2 x 5 factorial design, with two products (product “A”: 780.0 $g.L^{-1}$ of zinc and product “B”: 182.4; 7.6 and 45.6 $g.L^{-1}$ of zinc, boron and molybdenum, respectively) and five dosages of the products: 0, 1, 2, 3 and 4 $mL.kg^{-1}$ of seeds), totaling 10 treatments, with four repetitions. After treating the seeds with fungicides belonging to the phenylpyrrole + acylalaninate group and the active ingredient fludioxinil + metalaxyl-M (25 $g.L^{-1}$ + 10 $g.L^{-1}$), commercial brand name (Maxim-XL®) at a dosage of 1 mL. kg^{-1} of seed. Finally, the seeds were coated with a polymer (Sepiret®) at a dosage of 2.5 mL. kg^{-1} of seeds. A volume of 8 $mL.kg^{-1}$ of seed was applied in all the treatments.

Seed applications were made in the following order: first the nutrients followed by the fungicide together with water and lastly the polymer and water. The products were placed in the bottom of a plastic bag and distributed up to a height of about 15 cm. Then 0.200 kg of seeds were placed inside the plastic bag and shaken for three minutes before being placed to dry at ambient temperatures for 24 hours (Nunes, 2005). After coating, seed quality was evaluated using the following tests:

Germination (G): with four repetitions of 50 seeds for each treatment. Seeds were sown on a paper substrate previously moistened with distilled water at a ratio of 2.5 times the weight of the dry paper with the rolls being kept in a germinator at 20 °C. Evaluations were made eight days after sowing according to the Rules for Seed Analysis (Brasil, 2009) and the results expressed as a percentage of normal seedlings.

First germination count (FGC): determined four days after sowing during the germination test.

Accelerated aging (AA): in a “gerbox” type box with a metal mesh, with 40 mL of distilled water added to the bottom of each box and the uniform distribution of seeds in a single layer on the mesh and placed in a BOD-type incubator at 41 ºC for 72 hours. The seeds were submitted to the germination test after this period and evaluated on the fourth day after incubation.

Seeds were also sown in a greenhouse in 15 L pots filled with sieved “Planossolo Háplico Eutrófico solódico” soil, collected from the A1 horizon (Embrapa, 2006), belonging to the Pelotas mapping unit. Fertilizer was applied according to the soil analysis results and the recommendation of the Chemical and Soil Fertility Commission - RS/SC (2004) and the Technical Information Manual for Wheat and Triticale – 2010 crop. Only nitrogen, phosphorus and potassium were used and applied 14 days before sowing and liming was also done thirty days before sowing.

Twelve seeds were sown per pot and seven plants were left after thinning. Irrigation was daily, keeping the soil close to field capacity. Samples were taken to evaluate initial growth and the following determinations were made: foliar area of the aerial part (FA), plant height (PH) and the dry weight of the aerial part (DWAP). For these determinations, one plant per pot was chosen at random and cut at soil level 10, 20 and 30 days after emergence (DAE). FA was determined using a photoelectric meter (model LI-3100 Area Meter, from Li-cor Ltd.), which gives a direct reading in cm^2. PH was measured with a graduated ruler and the results expressed in centimeters. The DWAP was calculated by keeping the plants in an oven at 60 ºC for 72 hours and weighing on an analytical balance to two decimal places. With the results from the foliar area and dry weight of the aerial parts, the following parameters were determined: crop growth rate – CGR ($mg.\ day^{-1}$); relative growth rate – RGR ($mg.g^{-1}.day^{-1}$); net assimilation rate – NAR ($mg.\ cm^{-2}.\ day^{-1}$). These calculations were based on the methodology described by Gardner et al. (1985), in which: $CGR = (DM_2 – DM_1)/(T_2 – T_1)$; $RGR = (\ln DM_2 - \ln DM_1)/(T_2 – T_1)$; $NAR = (DM_2 – DM_1)/(T_2 – T_1) * (\ln FA_2 - \ln FA_1)/(FA_2 – FA_1)$; with: DM: dry material, T: time, FA: foliar area.

Manual harvesting was done when the 2/3 of the spikelets were light yellow or cream colored, characterizing physiological maturity. The quality of the seeds produced was evaluated with the germination (G), first germination count (FGC) and accelerated aging tests (AA) described previously.

Cold Tests (CT): done with four sub-samples of 50 seeds for each experimental unit, with the paper rolls placed in plastic bags, which were sealed and kept in a chamber at 10 ºC for seven days. After this period, they were transferred to a germinator and kept under the same conditions as the germination test and evaluated after four days (Cícero and Vieira, 1994).

Hectoliter weight (HW): with three repetitions and using a specific balance with a capacity for 1 L of seeds, and the result was expressed in kg. hL^{-1}.

Seed yield (Y): determined by weighing the harvested seed and correcting water content to 13%.

The experimental design adopted was entirely random with a 2 x 5 factorial (2 products and 5 dosages) and four repetitions. The results were submitted to an analysis of variance and further analyses were made when there was a significant interaction. Means were compared using the Tukey test at the 5% probability level. Statistical analyses were made using version 2.0 of the Winstar Statistical Analysis System (Machado and Conceição, 2003).

Results and Discussion

The data in Table 1 show that products "A" and "B" did not significantly affect the physiological quality of the treated seeds up to a dosage of 4 $mL.kg^{-1}$. However, for the first count and germination tests those seeds treated with product "A" with 780.0 $g.L^{-1}$ of zinc showed a better performance than those treated with product "B" composed of the nutrients Zn, B and Mo, at the dosages of 182.4; 7.6 and 45.6 $g.L^{-1}$, respectively, although a significant dosage effect was not observed. These results agree with those of Ohse et al. (2000), who concluded that coating seeds with zinc did not affect germination and vigor. Funguetto et al. (2010) analyzed coating rice seeds with zinc, fungicide and a polymer and they also did not observe any changes in germination. However, Yagi et al. (2006) noted a reduction in the percentage germination of sorghum seeds treated with zinc. Results from the accelerated aging test demonstrated that seeds treated both with product "A" and product "B" showed no significant difference when exposed to conditions of high temperature and relative humidity.

Table 1. First germination count (FGC), germination (G) and accelerated aging (AA) of wheat seeds coated with micronutrients.

Dosage ($mL.kg^{-1}$)	Product					
	A[1]	B[2]	A[1]	B[2]	A[1]	B[2]
	FGC (%)		G (%)		AA (%)	
0	87	86	89	87	79	78
1	89	84	90	86	80	78
2	90	85	91	87	81	80
3	90	86	91	88	80	79
4	89	85	91	87	79	79
Mean	89 A*	85 B	90 A	87 B	80 A	79 A
C.V. (%)	3.2		2.7		3.8	

*Means followed by the same capital letter in the row for each variable do not differ among themselves according to the Tukey test at the 5% probability level.[1]Product "A": 780.0 $g.L^{-1}$ of zinc; [2] Product "B": 182.4; 7.6 and 45.6 $g.L^{-1}$ of zinc, boron and molybdenum, respectively.

Table 2 shows the results for wheat plant growth 10, 20 and 30 days after emergence (DAE). Wheat seeds coated with the products "A" (based on Zn) and "B" (based on Zn and with Zn combined with B and Mo), were unaffected by these products, independently of the dosage applied, for plant height, foliar area and plant dry weight up to 30 DAE. The maximum dosage used of product "A" was 3.1 g of Zn per kg of seed whereas that of product "B" was 0.72, 0.03 and 0.18 $g.Kg^{-1}$ of seed with Zn, B and Mo, respectively.

The dry weight data obtained were similar to those reported by Bonnecarrère et al. (2004) in rice, who found no influence from zinc sources applied with seed treatment. Thus the application of Zn via seeds resulted in no significant effect on the dry matter of the aerial parts or of any of the other parameters evaluated and this was confirmed by results from Bonnecarrère et al. (2004). However, the current results disagreed with those of Rozane et al. (2008), who found that a dosage of 0.86 g of Zn.Kg^{-1} of seed, as zinc sulfate, contributed significantly to an increase of 48% in dry plant weight for rice when compared to the control.

Table 2. Plant height (PH), foliar area (FA) and dry weight of aerial part (DWAP) of wheat plants originating from seeds coated with micronutrients, at 10, 20 and 30 days after emergence (DAE).

Period	Dosage (mL.kg^{-1})	Product					
		A[1]	B[2]	A[1]	B[2]	A[1]	B[2]
		PH		FA		DWAP	
10 DAE	0	12.2	12.2	5.1	5.1	25.9	25.9
	1	12.3	12.3	5.4	5.3	26.2	25.9
	2	12.3	12.3	5.4	5.3	26.3	26.0
	3	12.4	12.4	5.5	5.4	26.5	26.2
	4	12.3	12.3	5.4	5.3	26.4	26.1
	Mean	12.3 A*	12.3 A	5.4 A	5.3 A	26.3 A	26.0 A
	C.V.(%)	8.1		16.2		5.5	
20 DAE	0	16.9	16.9	26.7	26.7	101.8	101.8
	1	16.9	17.0	28.2	27.7	102.8	101.7
	2	17.0	17.0	29.3	27.9	103.1	102.0
	3	17.1	17.1	31.2	28.0	103.9	102.8
	4	17.0	17.0	29.1	27.7	103.7	102.6
	Mean	17.0 A*	17.0 A	29.5 A	27.8 A	103.4 A	102.3 A
	C.V.(%)	8.1		7.5		7.5	
30 DAE	0	32.3	32.3	48.7	48.7	205.2	205.2
	1	34.4	33.0	50.8	48.4	212.5	207.7
	2	36.0	33.4	54.7	52.3	228.8	224.0
	3	41.5	36.9	58.2	56.8	244.8	247.5
	4	38.5	36.3	56.3	54.7	231.7	236.9
	Mean	37.6 A*	34.9 A	55.0 A	5.0 A	229.5 A	229.0 A
	C.V.(%)	9.4		9.1		12.0	

*Means followed by the same capital letter in the row for each variable do not differ among themselves according to the Tukey test at the 5% probability level.[1] Product "A": 780.0 g.L^{-1} of zinc; [2] Product "B": 182.4; 7.6; and 45.6 g.L^{-1} of zinc, boron and molybdenum, respectively.

The coating of seeds with Zn, B and Mo did not cause any significant effect on plant height up to 30 DAE for either product, supporting the data from Lopes (1984) working with zinc application on rice seeds.

The crop growth rate shows the speed of plant growth, calculated from measurements made at different times. The relative growth rate represents the variation in the dry weight as a function of the initial dry weight during a time interval and the net assimilation rate expresses the weight of dry matter produced per unit foliar area per unit of time. Table 3 shows that there were no significant differences between wheat seeds coated only by zinc or together with B and Mo, up to a dosage of 4 mL kg^{-1} of seeds, for crop growth rates, relative growth rates or net assimilation rates during the initial growth stages. However, Bergmann (1992) believes that zinc deficiency can cause a reduction in the plant growth rate, stop leaf expansion and stem lengthening, as well as inhibit root growth. The results showed that zinc did not affect growth rates because the soil did not have any zinc deficiency.

Regarding seed yields, product "A", with 780.0 g.L^{-1} of Zn, was superior to product "B", with 182.4, 7.6 and 45.6 g.L^{-1} of Zn, B and Mo (Table 4). These results are similar to those of Ohse et al. (1999), who found that the number of panicles per irrigated rice plant varied according to the dosage of zinc applied to the seeds, with an estimated maximum of 5.94 panicles per plant for the optimum dosage of 0.76 g Zn.Kg^{-1} of seeds, equivalent to 114.0 g.ha^{-1} of zinc. However, Funguetto et al. (2010) and Orioli Junior et al. (2008) did not observe any differences between dosages of Zn for this variable and did not detect any differences in the number of spikelets in wheat seeds treated with zinc.

Seed quality results for products "A" and "B" at the treatment dosages, determined from the tests for cold, accelerated aging and first count germination, showed no effect on the vigor of the seeds produced. However, the germination of the seeds produced was improved, with product "A" at 780.0 g.L^{-1}, being better than product "B", with 182.4 g.L^{-1}, which may be attributed to a greater concentration of Zn being supplied. These data disagree with those of Vieira and Moreira (2005), who found no changes in the germination of rice seeds coated with zinc.

Table 3. Crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) of wheat plants originating from seeds coated with micronutrients up to 30 days after emergence (DAE).

Dosage ($mL.Kg^{-1}$)	Product					
	A[1]	B[2]	A[1]	B[2]	A[1]	B[2]
	CGR ($mg.pl^{-1}$ day^{-1})					
	Period					
	1 to 10 DAE		11 to 20 DAE		21 to 30 DAE	
0	2.59	2.59	7.59	7.59	10.33	10.33
1	2.62	2.59	7.67	7.58	10.97	10.60
2	2.63	2.60	7.69	7.60	12.57	12.20
3	2.65	2.62	7.75	7.66	14.09	14.47
4	2.64	2.61	7.73	7.65	12.80	13.43
Mean	2.63 A*	2.60 A	7.71 A	7.62 A	12.61 A	12.67 A
C.V. (%)	5.3		8.8		19.8	
Dosage ($mL.kg^{-1}$)	RGR ($mg.\ g^{-1}$ day^{-1})					
			11 to 20 DAE		21 to 30 DAE	
0	-	-	0.13	0.13	0.069	0.069
1	-	-	0.14	0.14	0.072	0.071
2	-	-	0.14	0.14	0.079	0.078
3	-	-	0.14	0.14	0.086	0.087
4	-	-	0.14	0.14	0.080	0.083
Mean			0.14 A*	0.14 A	0.077 A	0.078 A
C.V. (%)			3.73		13.8	
Dosage ($mL.kg^{-1}$)	NAR ($mg.cm^{-2}$ day^{-1})					
			11 to 20 DAE		21 to 30 DAE	
0	-	-	0.581	0.581	0.279	0.279
1	-	-	0.563	0.563	0.285	0.286
2	-	-	0.544	0.56	0.308	0.315
3	-	-	0.534	0.57	0.326	0.354
4	-	-	0.554	0.57	0.312	0.340
Mean			0.549 A	0.566 A	0.308 A	0.324 A
C.V. (%)			13.3		17.7	

*Means followed by the same capital letter in the row for each variable, do not differ among themselves according to the Tukey test at the 5% probability level.[1]Product "A": 780.0 $g.L^{-1}$ of zinc; [2]Product "B": 182.4; 7.6 and 45.6 $g.L^{-1}$ of zinc, boron and molybdenum, respectively.

Table 4. Yield of seed (Y), first germination count (FGC), germination (G), accelerated aging (AA), cold test (CT) and hectoliter weight (HW) of wheat seeds produced from seeds coated with micronutrients.

Dosage ($mL.Kg^{1}$)	Product											
	A[1]	B[2]	A[1]	B[2]	A[1]	B[2]	A[1]	B[2]	A[1]	B[2]	A[1]	B[2]
	Y ($g.pl^{-1}$)		FGC (%)		G (%)		AA (%)		CT (%)		HW ($kg.\ hl^{-1}$)	
0	15.3	15.3	67	67	84	84	73	73	77	77	76.3	77.8
1	16.4	15.3	67	67	87	84	74	73	78	77	76.1	77.2
2	17.5	15.8	68	68	88	86	75	74	78	77	77.2	77.3
3	17.7	16	68	67	90	85	75	75	78	78	77.7	76.6
4	16.9	16.5	67	66	88	84	74	74	77	78	76.6	77.3
Mean	16.7 A*	15.7 B	67 A	67 A	87 A	84 B	74 A	74 A	78 A	77 A	76.8 B	77.3 A
C.V. (%)	6.7		2.1		2.8		3.2		3.0		0.6	

*Means followed by the same capital letter in the row for each variable, do not differ among themselves according to the Tukey test at the 5% probability level.[1]Product "A": 780.0 $g.L^{-1}$ of zinc; [2]Product "B": 182.4; 7.6 and 45.6 $g.L^{-1}$ of zinc, boron and molybdenum, respectively.

The hectoliter weight (HW) is a variety characteristic influenced by environmental conditions during grain filling and, among a series of external factors, may be affected by seed water content and the chemical treatment. Product "B", composed of the nutrients Zn, B and Mo, was superior to product "A", with only Zn, for HW, with this variable together with the germination, seedling growth and development and seed viability, being important components for evaluating seed quality.

Figure 1 shows that there was no significant interaction between the factors and, therefore, a mean between product "A", with only Zn, and product "B", with Zn, B and Mo, was used. It can be seen from Figure 1 that an increase in dosage up to 4 $mL.kg^{-1}$ of seeds promoted a linear increase in plant height, foliar area and dry weight for both products, supporting the data obtained by Prado et al. (2007), when a better initial performance of wheat seedlings was observed after treating seeds with $ZnSO_4$.

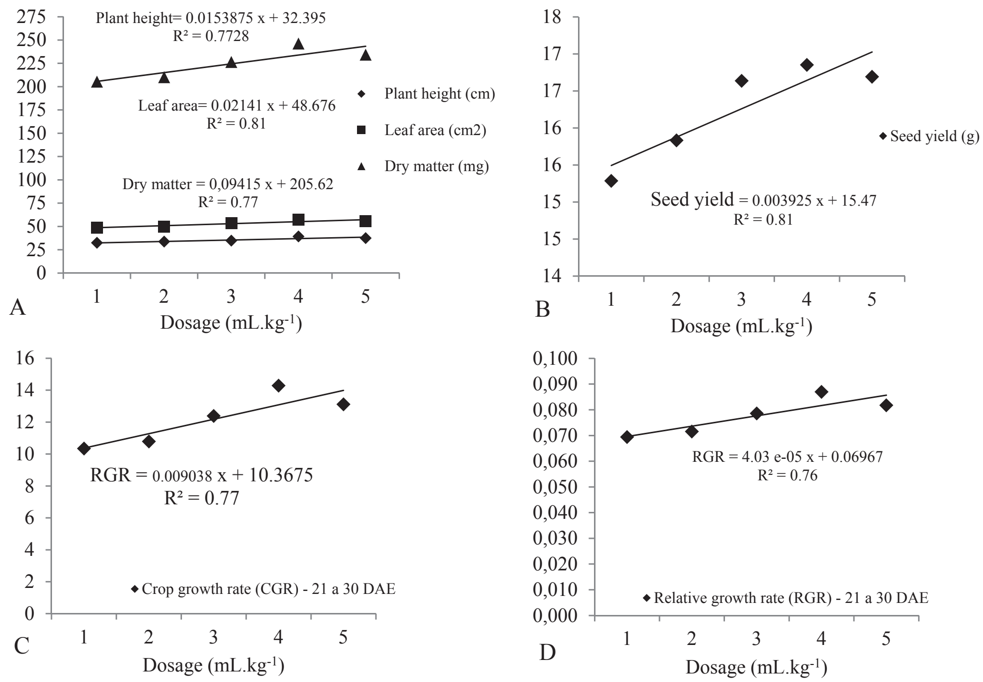

Figure 1. Mean values for plant height, foliar area and dry weight of the aerial part (A) 30 days after emergence (DAE), seed yield (B), crop growth rate (C) and relative growth rate (D) between 21 and 30 DAE, of wheat plants and seeds from seeds coated with products "A" (zinc) and "B" (zinc, boron and molybdenum).

The increase in dosage up to 4 $mL.kg^{-1}$ of seeds caused a linear increase in seed yield for both products (Figure 1B). These data confirmed those reported by Funguetto et al. (2010), who obtained a linear increase in the number of grains per panicle and in the weight of grains per plant with increasing dosages of zinc: a 29% increase in the number of grains per panicle and a 21% increase in the weight of grains per plant at the maximum dosage of 0.77 g $Zn.kg^{-1}$ of seeds, compared to a zero dosage of $Zn.kg^{-1}$ of seeds. This result was also observed by Oliveira (2007), who observed an increase in grain yield after treating soybeans with Acaplus (8.5% Zn + 7% N) at a dosage of 200 mL per 100 kg of seeds and an increase in yield for corn treated with the rooting products, Awaken (16.0% N; 3.53% Zn; 0.15% Mn; 0.15% Fe; 0.15% Cu; 0.02% B and 0.0006% Mo), at a dosage of 160 mL per18 kg of seeds. This result contradicts that of Ferreira et al. (2007) for mean grain yield in wheat and soybeans respectively, when biostimulants and fertilizers were applied in seed treatment.

The crop growth rate and the relative growth rate (Figures 1A and 1B) showed a linear increase for dosages up to 4 $mL.kg^{-1}$ for the period from 21 to 30 DAE. Therefore, it can be inferred that the absorption of the products "A" and "B" began after 20 DAE, resulting in a greater accumulation of photo-assimilates by the aerial plant parts.

Conclusions

The coating of wheat seeds with product "A", with a zinc basis, and product "B", composed of zinc, boron and molybdenum, respectively, up to a dosage of 4 $mL.kg^{-1}$ of seeds, did not adversely affect the physiological quality of treated seeds and those produced.

Both products resulted in a greater foliar area, plant height and plant dry weight up to 30 days after emergence as well as giving a higher seed yield.

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