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Initial Development of Wheat and Triticale under Different Sowing Depth

Magaiver Gindri Pinheiro, Clovis Arruda Souza, João Francisco Costa Carneiro Junior, Elijanara Raissa Silva and Deivid Luis Vieira Stefen

Santa Catarina State University (UDESC), Agronomy Department,
Laboratory of Crop Science, Lages, Santa Catarina State, Brazil

Abstract: Sowing depth is among the management practices that could have the highest influence on seedling emergence, plant stand, crop performance and, therefore, on productivity. This work aimed to assess the influence of sowing depth on the emergence and initial development of three wheat cultivars and one triticale cultivar. Randomized blocks were used as experimental design, arranged in a 4 × 4 factorial design. The factors consisted of four cultivars - three of them were wheat cultivars "TBIO Toruk", "BRS Marcante" and "Abalone" and one was a triticale cultivar "BRS Resoluto" - and four depths of sowing: 5; 6; 7 and 8 cm. The emergence speed index and accumulated dry weight were both affected by the interaction between cultivar × depth. Emergence and mesocotyl length were individually affected by the cultivar and depth. The best performance was obtained at a sowing depth of 5 cm, highest emergence associated with highest emergence speed index; among genotypes, the triticale cultivar "Resoluto" was the most negatively affected by sowing depth and pointing to a reexamination in sowing depth suitable as lowest than 5cm.

Key words: *Triticum aestivum* · *X Triticosecale* Wittmack · Stand · Emergence.

INTRODUCTION

Wheat is considered the second most cultivated crop in the world in what concerns grain production, having human feeding as its main destination [1]. According to the U.S. Department of Agriculture [2], Brazil is responsible for about 6% of the world wheat production. The 2017/2018 crop presented a 36% reduction in the production of this cereal in Brazil when compared to the previous crop period. According to the National Supply Company (Conab) [3], the new cultivars available on the market can now exceed the productivity that is set at 6 tons/ha with the advances in genetic improvement and the use of proper management practices; the national average is 3 tons/ha. Wheat is also used to produce animal rations, having its cropping limited to ecologically fit areas. From this perspective, triticale (*X Triticosecale* Wittmack), resulting from hybridization between wheat (*Triticum aestivum*) and rye (*Secale cereale*), matches the favorable characteristics of both species, thus granting advantages, especially in regions where winter cereals cultivation is not recommended [4]. The Brazilian production of triticale has been presenting an ascending curve in the last few years, which demonstrates the potential of this crop in the production system [3].

Sowing depths is among the management practices that could have the highest influence on plant stand, seedling emergence, crop performance and, therefore, on productivity. High-depth sowing can cause an increase on the epicotyl and hypocotyl lengths and also on the time between germination and seedling emergence, which might result in a fault on the plant stand [5]. However, some authors infer that a greater sowing depth can favor the establishment of wheat crop, due to greater water content in contact with the seeds in such conditions, which might result in a higher germination and seedling emergence index [6, 7]. According to Heydecker [8], seeds should be sown deep enough so that there is continuous water supply and support for seedling emergence. However, the Brazilian Commission for Wheat and Triticale Research [9] recommends a generic value from 2 to 5 cm of sowing depth for both crops; this management practice, however, can be different when factors such as diversity in soil, climate and existing cultivars in fit-for-

Corresponding Author: Clovis Arruda Souza, Santa Catarina State University (UDESC), Agronomy Department, Laboratory of Crop Science, Lages, Santa Catarina State, Brazil.

cultivation areas are considered. However, for triticale few information's about the effects of sowing depth for current cultivars on the emergence and effective plant stand for triticale and wheat.

With the purpose of shifting the current falling status in Brazilian production and productivity, given the wide offer of cultivars currently in the market, this paper had the objective to assess the influence of sowing depth on the emergence and initial development of three wheat cultivars and one triticale cultivar.

MATERIALS AND METHODS

Field Sites and Experimental Design: The experiment was conducted in the 2017 growing season in experimental seedbeds containing soil at Santa Catarina State University (UDESC), in Lages, located at the Southern Plateau of the State of Santa Catarina, Brazil. The average altitude is 930 m, 27°48'58" south latitude and 50°19'34" west longitude. Summers are mild and the average temperature is 15°C (59°F), with annual rainfall of 1,500 mm [10]. According to the Brazilian Commission for Wheat and Triticale Research [9], this location is inserted in the wheat production area 1 (high, humid and cold). Fig. 1 presents data on the maximum and minimum temperatures and rainfall during the experiment development.

Randomized blocks were used as experimental design, with a 4-repetition, arranged in a 4 × 4 factorial design. The factors consisted of four cultivars - three of them were wheat cultivars "TBIO Toruk", "BRS Marcante" and "Abalone" and one was a triticale cultivar "BRS "Resoluto" - and four depths of sowing (5 cm; 6 cm; 7 cm and 8 cm). The soil that was used is classified as Cambisol and the soil analysis presented the following results: organic matter 4%; P 15.15 mg/dm^3; K 195 mg/dm^3; pH (H_2O) 6.8; CEC 18.5 cmol$_c$/dm^3. Fertilizer and pH adjustments were performed according to the recommendations by the Soil Chemistry and Fertility Commission of Rio Grande do Sul and Santa Catarina (CQFS-RS/SC) [11] for wheat and triticale crops, aiming at a grain productivity potential of 5 tons/ha. Soil was regularly buffered and sifted in a sieve with a mesh measuring 1 cm and the depths were leveled having as reference the upper base of the seedbed; later, it was carefully covered until this same base (Fig. 2). Sowing was handled carried out on March 10th, 2017; 100 seeds (per repetition) were distributed with a regular space of 2.4 cm between each other. Weed control was performed by hoeing. Irrigation was performed once a day, aiming at making up for potential evapotranspiration.

Emergence Measurements and Initial Development Evaluations

Emergence (E): It was obtained from the total number of emerged plants in each repetition per treatment through the equation: E (%) = (N/100) × 100, where: N = number of emerged seedlings at the end of the experiment.

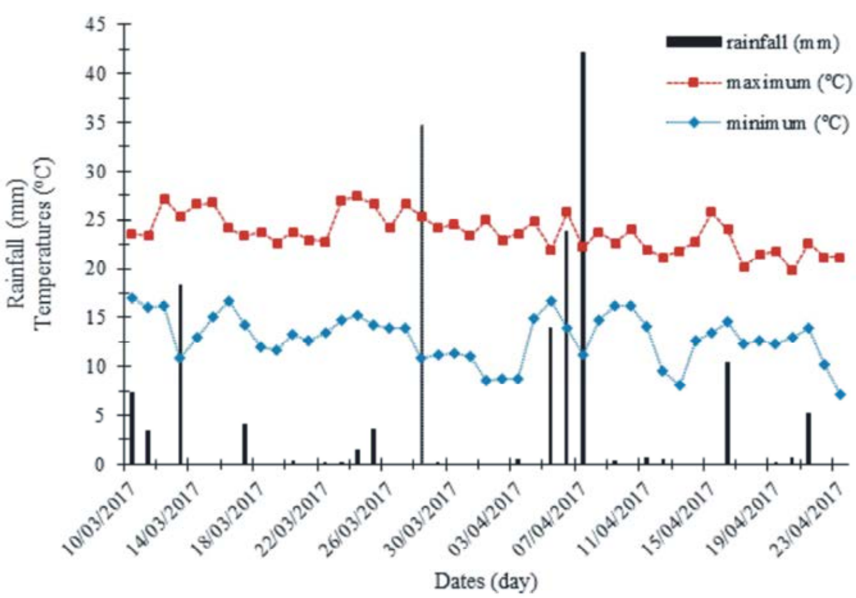

Fig. 1: The rainfall, maximum and minimum temperatures during the experiment. Lages, State of Santa Catarina, 2017 season.

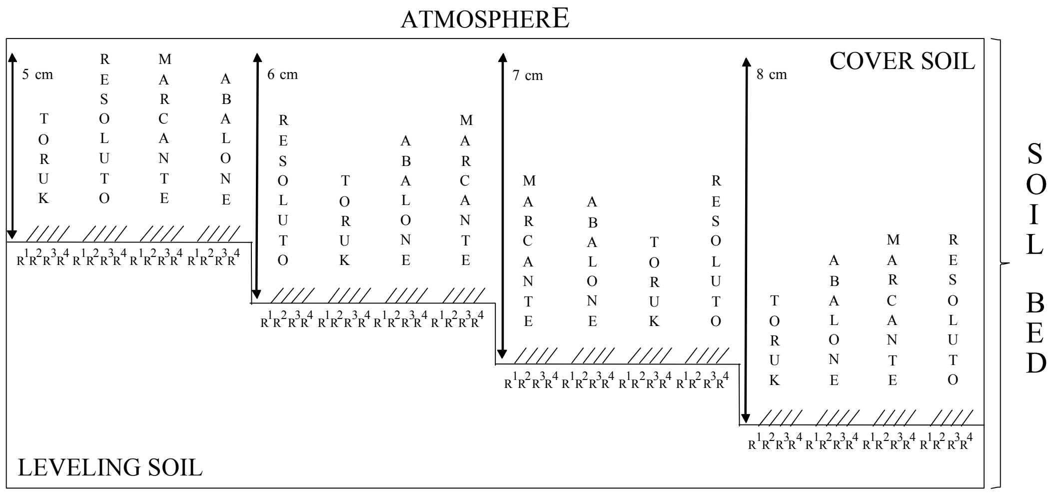

Fig. 2: Schematic assay layout design of the experiment implantation.

Emergence Speed Index (ESI): The ESI was obtained from the daily record of the number of emerged seedlings with aerial part formed until the eighth day, when the emergence was stabilized. The method used was the one proposed by Maguire [12], with the equation $ESI = E_1/N_1 + E_2/N_2 +. .. E_n/N_n$, where: ESI = emergence speed index; E_1, E_2,. .., E_n = number of normal seedlings on the first, second and final data collection; N_1, N_2,..., Nn = number of days passed between the sowing day and the day of the first, second and final data collection.

Mesocotyl Length: The measurement of seedling characteristics was made after the total seedlings of each plot were harvested and forwarded to the laboratory for measurements. The mesocotyl length was obtained from the average of the total seedlings of each treatment, from the measure of the distance between the seed until the crown base of each seedling.

Seedling Dry Weight: The total seedlings obtained in each treatment were taken to the oven with forced circulation of air at a 60°C (140°F) temperature until constant weight and later weighted using a precision scale (0.0001 g), thus obtaining the accumulated dry weight per seedling for each treatment.

Statistical Analysis: Data was processed and submitted to homogeneity and normality analysis tests, then to an analysis of variance using F-test. When significant variances were detected, the means were submitted to a Tukey's test at a 5% probability rate and to a regression analysis for the depths.

RESULTS

An interaction between the treatments for the factors cultivar and depth for the emergence speed index (ESI) and accumulated dry weight per seedling (DW) was reported (Table 1). For ESI, among the four cultivars, "Abalone" was the one that significantly stood out when compared to the others in depths of 5 cm, 6 cm and 7 cm, while triticale was the one that obtained the lowest emergence speed, thus being statistically different from all the other wheat cultivars in the same depths (Fig. 3). Wheat cultivars "Marcante" and "Toruk" presented similar behavior for this same variable in the four depths that were studied. When submitted to the depth of 8 cm, all genotypes maintained similar emergence speed (Fig. 3).

The four cultivars presented a decrease in the ESI with linear adjustment on the basis of the increase in the sowing depth. Cultivars "Abalone" and "Marcante" presented a higher ESI in the depths of 5 cm followed by 6 cm, while only the depth of 5 cm promoted a significant increase on cultivars "Toruk" and "Resoluto" (Fig. 4). Wheat cultivars presented an average decrease of 76% in the ESI when the two deepest depths were compared. Although the ESI of triticale is lower when compared to wheat cultivars, its decrease was of 69% when having the basis of the deepest depths, which demonstrates a smaller range of variation with the increase in depth, since it presented the lowest angular coefficient (0.249).

The emergence was individually affected by the factor cultivar and depth (Table 1). The four cultivars had significant differences among themselves (Fig. 5). Cultivar "Abalone" stood out with a mean of 71.8%, followed by

Table 1: Summary of the analysis of variance, mean square and significance for emergence speed index (ESI), emergence (E), mesocotyl length (ML) and accumulated dry weight per seedling (DW) of three wheat cultivars “Abalone”, “Marcante”, “Toruk” and one triticale cultivar “Resoluto” submitted to four depths of sowing. Lages, 2017 season

		Traits			
SOV	DF	ESI	E	ML	DW
		MS			
Block	3	0.013	0.061	0.60	1.19
Cultivar (C)	3	0.255**	0.445**	9.08**	18.10**
Depth (D)	3	0.756**	0.231**	39.42**	19.07**
C × D	9	0.018*	0.023	0.52	7.48**
Residual	45	0.007	0.021	0.29	0.46
CV (%)		6.24	8.77	13.53	15.47

SOV: source of variation; DF: degree of freedom. CV: coefficient of variation.
* and ** significant at 0.05 and 0.01 probability levels, respectively, by F-test.

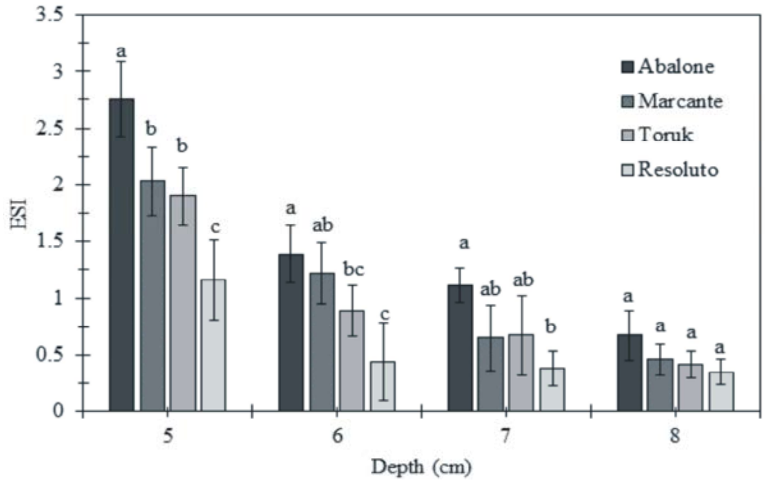

Fig. 3: Interaction sowing depth × cultivar on emergence speed index of three wheat cultivars “Abalone”, “Marcante” and “Toruk” and one triticale cultivar “Resoluto”. Lages, 2017 season. Vertical bars are standard error of the mean.

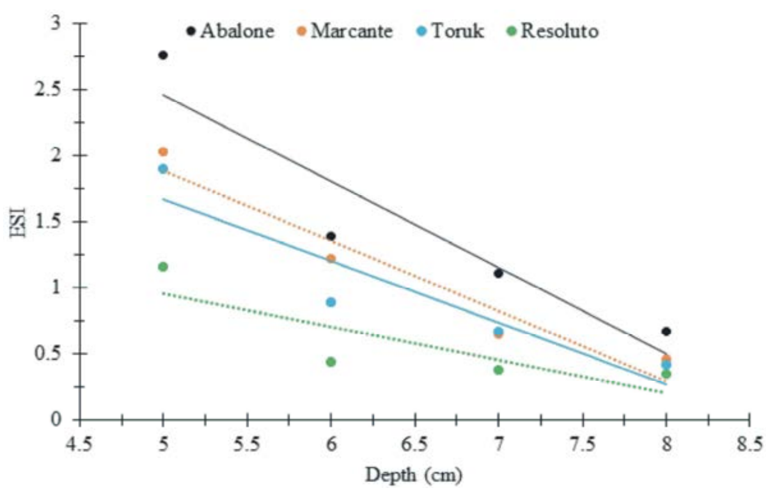

Fig. 4: Emergence speed index of three wheat cultivars “Abalone” (black; $y = -0.655x + 5.74$, $R^2 = 0.8807$), “Marcante” (orange; $y = -0.528x + 4.522$, $R^2 = 0.9331$), “Toruk” (blue; $y = -0.466x + 3.999$, $R^2 = 0.8587$) and one triticale cultivar “Resoluto” (green; $y = -0.249x + 2.201$, $R^2 = 0.6838$) on the basis of the increase in the sowing depth. Lages, 2017

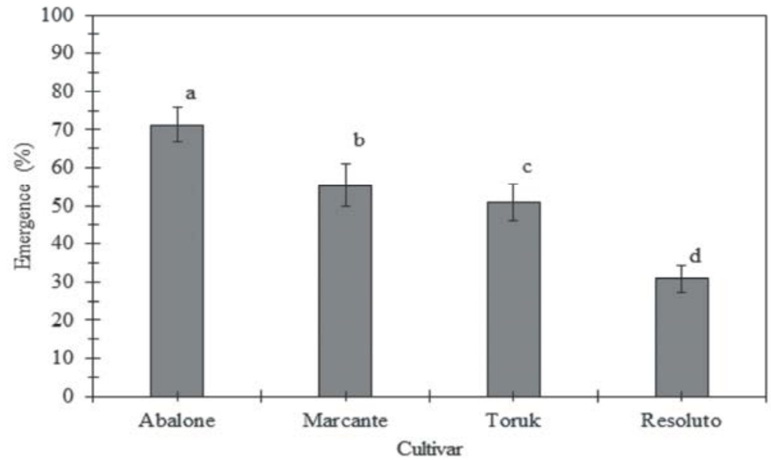

Fig. 5: Single effect of seedling emergence of three wheat cultivars “Abalone”, “Marcante” and “Toruk” and one triticale cultivar “Resoluto”. Lages, 2017 season. Vertical bars are standard error of the mean.

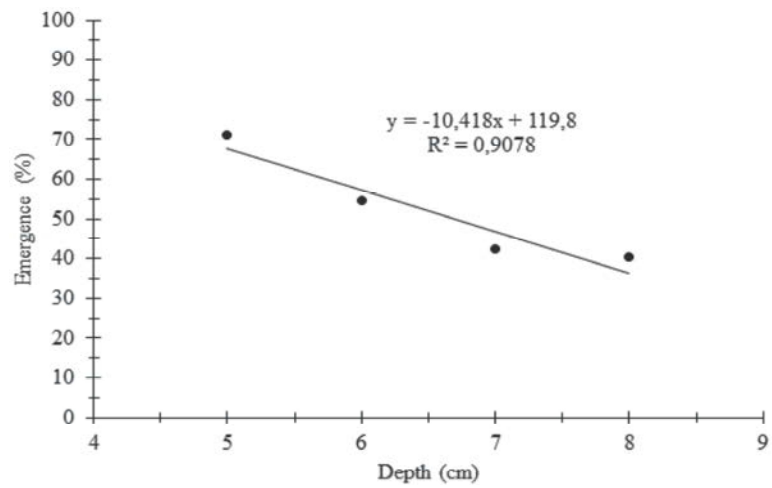

Fig. 6: Single effect of sowing depth on seedling emergence of three wheat cultivars “Abalone”, “Marcante” and “Toruk” and one triticale cultivar “Resoluto”. Lages, 2017 season.

a decreasing behavior from cultivars “Marcante”, “Toruk” and “Resoluto”, for which the means of 55.4, 50.8 and 30.8 were observed, respectively. The same decreasing behavior was observed for this same variable when having the basis of depths. The increase in depth promoted a decrease (linear adjustment), with a fall of 10.4% of emergence for each 1 cm of increase in the sowing depth, in a similar manner among genotypes (Fig. 6).

The accumulated dry weight was affected by the interaction between cultivar and depth (Table 1). The cultivars presented a more heterogeneous behavior for this variable. Cultivar “Abalone” stood out with the highest dry weight accumulation when in depths of 5 cm and 6 cm, while in depths of 7 cm and 8 cm triticale cultivar “Resoluto” was the one that significantly stood out from the others for the same variable. Cultivar “Toruk” presented an intermediate behavior in relation to the others, while cultivar “Marcante” obtained the lowest accumulated dry weight in every studied depth (Fig. 7).

Cultivar “Abalone” presented a square adjustment for accumulated dry weight (Fig. 8); the other cultivars had an increase, with linear adjustment, in the dry weight accumulation with the increase in the sowing depth (Fig. 8). The depth of 5 cm promoted a significant increase on cultivar “Abalone”, while the depths of 6 and 7 cm promoted the lowest dry weight accumulation for the same cultivar. The depths of 7 and 8 cm promoted a significant increase on triticale cultivar “Resoluto” in relation to the other depths of 5 and 6 cm, while only the depth of 8 cm significantly stood out for cultivars “Marcante” and “Toruk” in relation to the

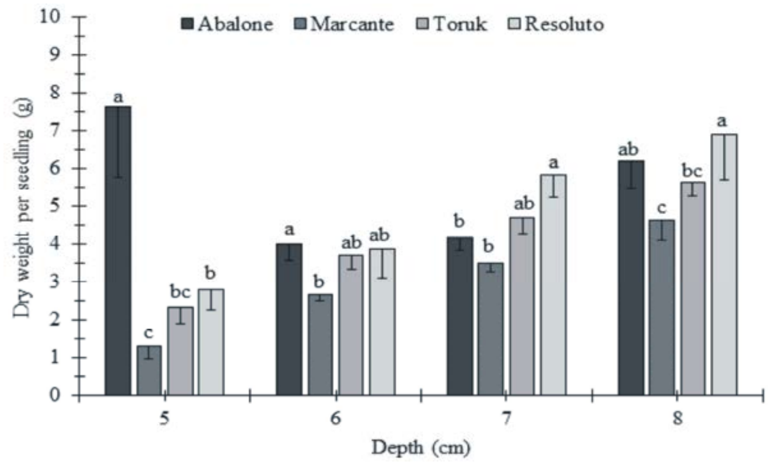

Fig. 7: Interaction sowing depth × cultivar on dry weight per seedling of three wheat cultivars “Abalone”, “Marcante” and “Toruk” and one triticale cultivar “Resoluto”. Lages, 2017 season. Vertical bars are standard error of the mean.

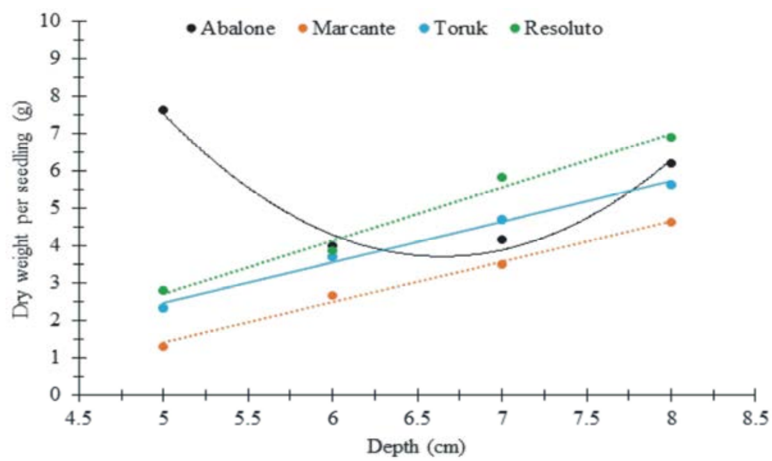

Fig. 8: Interaction sowing depth × cultivar for accumulated dry weight per seedling of three wheat cultivars “Abalone” (black; $y = 1.4075x2 - 18.709x + 65.877$, $R^2 = 0.9784$), “Marcante” (orange; $y = 1.078x - 3.982$, $R^2 = 0.9926$), “Toruk” (blue; $y = 1.092x - 3.008$, $R^2 = 0.9915$) and one triticale cultivar “Resoluto” (green; $y = 1.425x - 4.405$, $R^2 = 0.9851$) on the basis of the increase in the sowing depth. Lages, 2017.

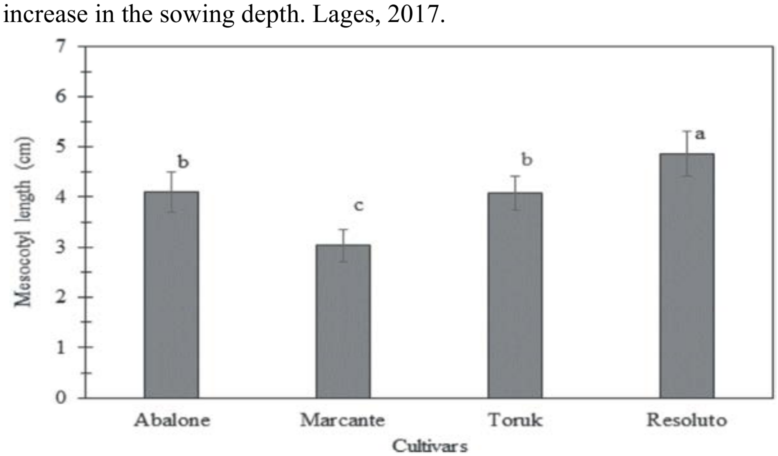

Fig. 9: Single effect for mesocotyl length of three wheat cultivars “Abalone”, “Marcante”, “Toruk” and one triticale cultivar “Resoluto” on the 40th day after sowing. Lages, 2017 season. Vertical bars are standard error of the mean.

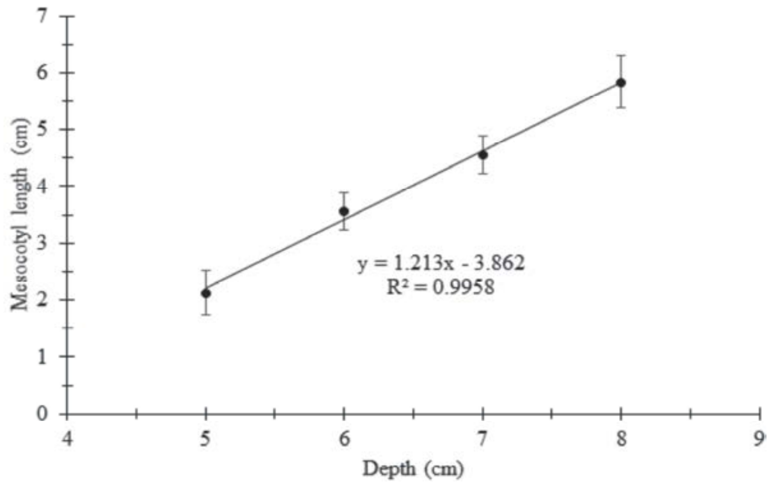

Fig. 10: Single effect for mesocotyl length as a function of the increase in the sowing depth. Lages, 2017 season. Vertical bars are standard error of the mean.

others. This depth presented the highest dry weight accumulation. The increase in seedling dry weight with increase in seed sowing depth is possible because a compensation due low seedling emergence observed (Fig. 6 × Fig. 8).

The mesocotyl length was affected individually by the factors cultivar and depth (Table 1). For cultivar "Resoluto", an average length of 4.48 cm was observed, which stood it out in comparison to the other cultivars. Cultivars "Abalone" and "Toruk" presented intermediate mean values for this variable, of 4.11 cm and 4.09 cm, respectively, significantly standing them out from cultivar "Marcante", which obtained the shortest mesocotyl length, of 3.03 cm (Fig. 9). A growing behavior with linear adjustment was observed for this same variable when the means of all cultivars were compared, due similar comportment, on the basis of the increase in the sowing depth (Fig. 10). The four depths were significantly different among themselves; for each 1 cm in sowing depth, the longest mesocotyl length was 1.213cm/cm (Fig. 10).

DISCUSSION

The reduction in the ESI significantly affects the establishment and plant stand, which in turn can affect the dry weight accumulation by plant and leaf area [13]. This is evidenced by the observation of the ESI values of the cultivars and the accumulated dry weight. It was possible to notice that lower ESIs demonstrated a tendency to increase the dry weight accumulation per plant due to an increase in the mesocotyl length, which could result in a delay on seedling emergence and unevenness on the plant stand. This unevenness on the plant stand can directly affect the production components that determine the grain yield, such as number of ears per plant, number of spikelets per ear, number of grains per ear and per spikelet and average grain weight, which depend on genetic and environmental factors [14]. Furthermore, seed vigor facing adverse conditions is inherent to each species and cultivar. Based on the observations and although the ESI of triticale is more affected with the increase in depth, it is possible to infer that this hybrid is less sensitive to variations in the sowing depth when compared to the wheat cultivars, given its lower angular coefficient (0.249) (Fig. 3).

According to Alves *et al.* [15], energy is necessary for a seedling to break the physical barrier and it comes from the seed reserves. Therefore, a higher consumption rate of such reserves can prevent the emergence due to the lack of energy. Another factor that might have an influence on this case is the low physiologic quality of seeds. According to Wrasse *et al.* [16], the reduction in seedling emergence depends on seed vigor; reductions in this vigor can slow the process down in up to 17%. The observations on the emergence of the cultivars suggest that triticale cultivar presents low vigor or greater difficulty to mobilize reserves from endosperm to the embryo. Then, the induction of activity of the enzymes that are responsible for the hydrolysis of the reserves could be measured through the exogenous application of phytohormone gibberellin, which induces the regulation of genes that codify for those enzymes [17] through signal transduction.

Sowing depth is a factor that can be decisive for the success of a crop. Coelho *et al.* [18] highlight that under abiotic stress, such as deep sowing, the potential of germination power and seedling vigor is associated with the capacity of the genotype to translocate and store nutrients in the seed. Furthermore, this management practice can affect the susceptibility of seedlings to pathogens, environmental variations and water deficit, given that the delay on emergence increases the period of fragility in the field [19].

The observations of accumulated dry weight demonstrated a clear relationship with the increase of the mesocotyl length, given the need of the seedling to emerge in search of sunlight, based on its positive geotropism. According to Casa *et al.* [20], deep sowings associated with humidity and cool temperature conditions on the soil can favor soil fungi that cause damages to the plants. When infected by pathogens, plants have biochemical defense mechanisms associated with the secondary metabolism, which can be quickly activated [21]. These defense lines of the plant through biochemical compounds will depend on the anabolism of biomolecules through genic expression, which will depend on the plant autonomy in producing its photoassimilates. Then, a mobilization of the energetic reserves in order to emerge delays the anabolism of important molecules which result in mechanical barriers and secondary metabolites that form the defense of the plants, thus increasing the susceptibility period.

Seed vigor in the face of adverse conditions is inherent to species or cultivar and the initial development may be affected by several factors. For example, storage of wheat seeds in different vial types affects germination and morphometric roots traits [22]. Further, pre-sowing treatments with polyethylene glycol (PEG) can synchronize germination and respective seedlings emergence in addition to promoting growth increase of wheat seedlings [23]. Therefore, germination and emergence of wheat seeds are dependent on physical and physiological factors as like sowing depth.

In this context, crops that are implanted by vegetative propagules are also influenced by the planting depth, for example, Nasir *et al.* [24] observed the negative relation between garlic bulb weight and planting depth affecting vegetative and productive parameters in the specie. Depth of planting is very important for plant establishment. But other agricultural practices are also susceptible to depth, for exemple, fertilizer management, Rahman *et al.* [25] observed that urea granules deposition at greater depth promoted a decrease in productive and morphometric components in rice plants.

Although the importance of sowing depth is recognized, most research has neglected this information, since in most research with wheat and triticale, this information has been omitted from the methodological description in the published articles on these crops [26, 27, 28, 29, 30].

CONCLUSION

The best performance was recorded in a sowing depth of 5 cm (1.9 in) gave the highest number of seedlings combined to a better emergence speed index. While the deepest depths negatively affect the emergence and initial development of wheat cultivars “Abalone”, “Marcante” and “Toruk” and triticale cultivar “Resoluto”. The wheat “Abalone” showed highest seed quality and consequently seedling performance. The triticale “BRS Resoluto” showed lowest seed quality and consequently seedling performance, make is the most affected by sowing depth when compared to wheat cultivars “Abalone”, “Marcante” and “Toruk”. Therefore, these results point to a reexamination in sowing depth suitable for triticale on basis in other cultivars and in its seed quality aimed an actual-correct recommendation for cropping Brazilian triticale cultivars.

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