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Mechanical Damage in the Tillering, Development and Productivity of Wheat

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Authors' contributions

This work was carried out in collaboration with all authors. Authors read and approved the final manuscript. Authors declare there aren't competing interests.

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ABSTRACT

Wheat has great economic importance, especially in the Southern states of Brazil, is a good option for winter cultivation period. The aim of this study was to evaluate the effect of mechanical damages in the induction of tillering, development and productivity of wheat. Treatments were two methods of mechanical damages (kneading and cutting) combined with five induction time of damages (seedling emergence, 7, 14, 21 and 28 days after emergence) and one control (no mechanical damages). Variables evaluated were: tillering, final height of plant, final length of spikes, final number of spikes per m^2, number of spikelets per spike and grain yield. The mechanical damages caused by the cutting method did not have positive effects on tillering, development and productivity of the wheat grain at any time of the cut. The kneading method did

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not increase tillers and productivity, nor did it reduce the number of tillers and productivity. The results, despite not being conclusive, demonstrate to be of the potential of cultivating wheat in an integrated crop-livestock system.

Keywords: Triticum aestivum cv. CD 107; winter cultivation; phenological stages; integrate crop-livestock; pasture-management.

1. INTRODUCTION

Wheat has great importance in the Brazilian agricultural scene with planted area of about 1,9 million hectares [1]. This crop is one of the most important options for winter cultivation. The states of Paraná and Rio Grande do Sul are responsible for more than 85% of the national production [2].

In the Southern region of Brazil, spring wheat cultivation is dominant, with the sowing done in autumn. The leaves growth and development occur during winter, and the flowering and grain filling occur in spring [3]. Thus, the development cycle of this crop, from emergence to physiological maturity, may be divided into two phases, vegetative and reproductive. When identification of the phases is based on external morphological indicators of easy identification on field, the vegetative phase may be considered from the emergence to the appearance of inflorescence or anthesis, whereas the reproductive phase begins from the end of the vegetative phase to physiological maturity [4,5].

Knowing the physiological and agronomic characteristics of a crop contributes to the development of production techniques. For wheat, one of these characteristics of wheat plant is the tiller, which is a modular unit presents in plants of Poaceae family. Tillering is important for production of the species, and it is expected that a higher number of tillers results in higher yields [6].

Several studies have been developed to assess the influence of tillers in grains yield. [7] claims that the tillering potential of the wheat is, however, not expressed in grains yield. On the other hand, studies with wheat showed significant gains in the evaluation of superior genotypes, in terms of grain yield, spike length, number of grains per spike and weight of one hundred grains under irrigation system [8].

In winter wheat, for the US state of Wisconsin, are recommends an increase in plants population from 1,300,000 to 1,750,000 plants per acre, when planting is carried out later, due to the low tillering of wheat under higher temperatures [9]. Thus, a positive effect is observed under cold temperatures on the increasing of tillering. This effect is the result of breaking apical dominance, caused by low temperatures, which consequently stimulates tiller is formation.

The defoliation causes mechanical stress in the plant due to the removal of leaf, and the defoliation intensity may affect in higher or lower degree the grain and forage yield [10].

The aim of this work was to evaluate the effect of mechanical damages in different times, in the induction of tillering, development, and productivity of wheat, replacing the low temperatures which occur in winter wheat, since in some years and regions did not occur enough low temperatures for stimulating a higher wheat tillering.

2. MATHERIALS AND METHODS

The experiment was carried out at the Experimental Farm of the Nucleus of Experimental Stations of the State University of Western Paraná (UNIOESTE), Marechal Cândido Rondon Campus located at Linha Guará (24°33’ of latitude S, 54°04’ W of longitude W and altitude 420 m a.s.l.).

Sowing was done mechanically in April using a mechanical seed planter. The chosen area had already been prepared under no-tillage system for four years under soybean residues. Planting density was 300 seeds per square meter, and spacing between lines was 0.17 m. The wheat cultivar used was CD 107, an early cycle cultivar. According to [11], the soil of the experimental area was classified as Eutroferric Red Latosol with 80% clay. All the necessary cultural practices were applied during the experiment. Top-dressing fertilizer was done at tillering stage, using 40 kg ha^{-1} of N in the form of ammonium sulfate. The plots were constituted by 14 lines of 5 m long, totaling 11.9 m^2. The useful area of the

Fig. 1. Mechanical damages in wheat plants: A: Road roller used for plants kneading; B: Appearance of plants with damages caused by cutting

plot was constituted by six central lines, eliminating 1.5 m of each extremity, totaling 2.04 m^2.

The experiment was conducted with a 2 x 5 + 1 factorial design, comprising two treatments, namely, mechanical damages (i.e., plants kneading and cutting) and five induction times of damages (i.e., seedling emergence, 7 days after emergence, 14 days after emergence, 21 days after emergence and 28 days after emergence) and a control (no mechanical damages). The experimental design was a randomized complete block with four replications.

Kneading and cutting were used for artificial induction of mechanical damages. Kneading was done by passing a road roller (Fig. 1A) transversely on the plants of each plot in a crop row, compressing the plants to the ground level at a compaction rate of 0.25 kg cm^{-2}. Cutting was performed by cutting the plants at 2.0 cm from the ground (Fig. 1B) using a gardening scissors.

The following evaluations were conducted at the end of the experiment: Tillering as a function of number of tillers per plant; the final height of plants, measuring from the stem to the apex of the spike (disregarding the arista); final length of spikes, measuring from the inferior extremity of the first spikelet on the spike base to the superior extremity of the last spikelet, (disregarding the arista). Both characteristics were determined on 10 randomly sampled plants in the useful plot. The following were also evaluated in addition: final number of spikes per m^2, counting the spikes from 3 lines of 2 meters long in the useful plot; number of spikelets per spike, counting the number of spikelets formed in each spike; and grain yield (kg ha^{-1}). Grain yield was evaluated by manually harvesting from the plots, converting total yield per the plot area to kg ha^{-1}, corrected at 13% humidity.

The data was subjected to analysis of variance, and posterior comparison of means by Tukey's test [12] using Genes software [13].

3. RESULTS AND DISCUSSION

The analysis of variance of the number of tillers per plant at the end of the study revealed that there was no significant statistical interaction between the mechanical damages and induction time. However, significant difference was observed between the mechanical damages, wherein, a higher number of tillers were recorded after kneading, but it did not differ of the control (Fig. 2A). The mean difference between the methods was less than one tiller per plant, what it seems to be a little difference, but it may be expressive if a commercial production is considered. The final number of tillers per plant was variable among plants, from zero to three, whose coefficient of variation was of 39.12%, considered very high according to [12] and it was also verified by [6] in the wheat tillering of the cultivar IAC370.

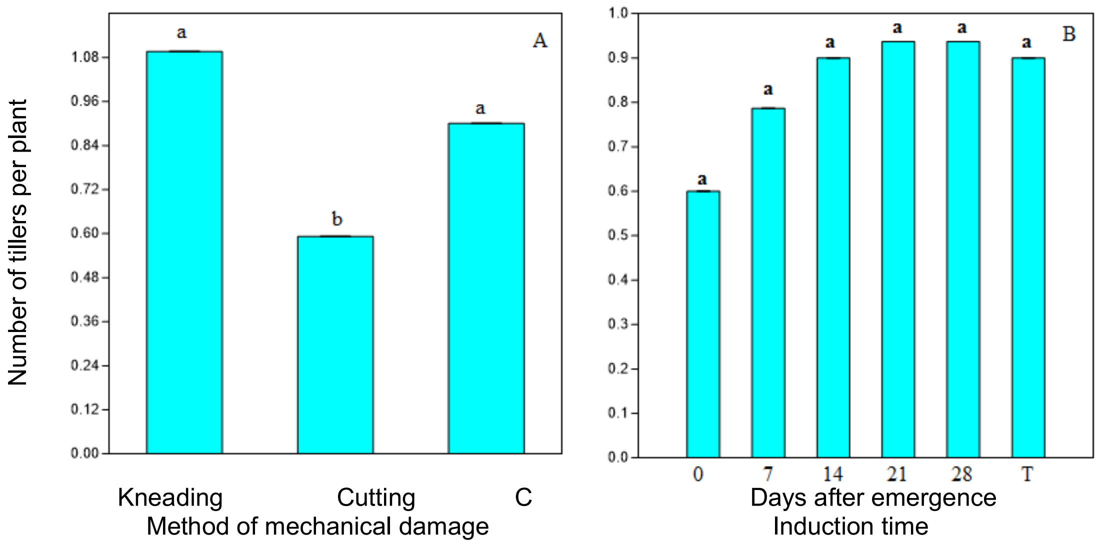

Fig. 2. Final mean number of tillers per wheat plant as a function of methods (A) and induction time (B) of mechanical damages in the wheat cultivar 'CD 107'

Means followed by equal letters do not differ from each other by Tukey test at 5% probability, being C the control, and the coefficient of variation of the experiment was of 39.12%

The interaction between the induction factors and time were significant ($P < 0.05$) for all the parameters evaluated in this study. Therefore, nested means were used to describe each factor within each level of another factor (Tables 1 to 5). It was observed that the coefficients of variation were less than 10% for the five parameters and were considered low according to the classification of [12], showing good experimental accuracy.

The final height of wheat is presented in Table 1. Induction time of kneading had no significant effect on plants heights. However, cutting resulted in significant height reductions at induction times between 7 to 28 days after. Cutting at 28 day resulted in the highest production, decreasing the size of the plant by 17.62 cm compared to the control. In the comparison with induction, plants height was lower than that from cutting, except when was done at emergence. The results show that cutting is not a beneficial management practice for wheat, since plant height is dependent on the shoot/stem height, which functions as a structure for translocation of assimilates, and hence, contributes to grain filling [14].

Kneading did not influence the final lengths of spikes at all induction times, except at 28 days after emergence, which was lower than that of the control and of kneading at 21 DAE. However, cutting resulted in shorter spike lengths, relative to the control for all cutting times (Table 2). The severity of cutting deleteriously affected the spikes lengths, due to depletion of the plants caused by the reduction of biomass during the late stress.

Table 1. Final height of wheat plants (cm) according to methods and induction time of mechanical damages in cultivar 'CD 107'

Induction times	Methods	
	Kneading	**Cutting**
Emergence	89.25 Aa	86.75 Aab
7 DAE	89.87 Aa	82.12 Bbc
14 DAE	89.75 Aa	81.25 Bc
21 DAE	87.50 Aa	81.50 Bc
28 DAE	85.37 Aa	72.25 Bd
Control	89.87 a	89.87 a
$CV_{(\%)}$	2.80	

DAE: Days after emergence; Means followed by equal letters, upper case in the horizontal and lower case in vertical, do not differ from each other by Tukey test at 5% probability

The final number of spikes per m^2 recorded under kneading was not significantly different relative to the control. However, for cutting at 14 and 28 DAE (Table 3), there was a significant reduction in the number of spikes m^{-2} compared to the control. The time (plant age) of cutting could have resulted in weakening the plants, causing plant senescence at 14 days, and abortion of tillers at 28 days after emergence.

This is important, since the establishment of strategies aimed at increasing productivity must cover the greater use of the agricultural land area or the field conditions [15,16].

Table 2. Mean values of the final length (cm) of spikes as a function of methods and induction time of mechanical damages in wheat cultivar 'CD 107'

Induction time	Methods	
	Kneading	Cutting
Emergence	6.89 Aab	6.09 Bb
7 DAE	6.88 Aab	6.28 Bb
14 DAE	6.82 Aab	6.07 Bb
21 DAE	6.91 Aa	5.81 Bb
28 DAE	6.40 Ab	5.79 Bb
Control	7.00 a	7.00 a
$CV_{(\%)}$	3.60	

DAE: Days after emergence; Means followed by equal letters, upper case in the horizontal and lower case in vertical, do not differ from each other by Tukey test at 5% probability

Table 3. Mean values of the final number of spikes per m^2 as a function of methods and induction time of mechanical damages in wheat cultivar 'CD 107'

Induction times	Methods	
	Kneading	Cutting
Emergence	371.20 Ab	345.32 Aabc
7 DAE	373.55 Ab	344.72 Aabc
14 DAE	424.10 Aab	308.25 Bbc
21 DAE	433.52 Aa	355.90 Bab
28 DAE	415.90 Aab	290.05 Bc
Control	384.12 ab	384.12 a
$CV_{(\%)}$	7.50	

DAE: Days after emergence; Means followed by equal letters, upper case in the horizontal and lower case in vertical, do not differ from each other by Tukey test at 5% probability

Comparing the two forms of mechanical damage, kneading resulted in a higher number of spikes per m^2 at 14, 21 and 28 DAE (Table 3). These results are similar to those reported for four different cultivars, subjected to cutting or non-cutting management practices, wherein cutting resulted in a smaller number of spikes [17]. This resulted from the stress caused by the cutting as presented earlier.

The number of spikelets per spike was statistically similar at all times under kneading, however, with regard to cutting, they were lower only when the damage was caused at 28 DAE (Table 4).

Table 4. Mean values of spikelets per spike as a function of methods and induction time of mechanical damages in wheat cultivar 'CD 107'

Induction time	Method	
	Kneading	Cutting
Emergence	15.55 Aa	15.92 Aa
7 DAE	16.05 Aa	16.10 Aa
14 DAE	15.95 Aa	15.47 Aa
21 DAE	16.30 Aa	15.10 Ba
28 DAE	14.85 Aa	12.25 Bb
Control	16.02 a	16.02 a
$CV_{(\%)}$	4.58	

DAE: Days after emergence; Means followed by equal letters, upper case in the horizontal and lower case in vertical, do not differ from each other by Tukey test at 5% probability

The differences between the methods of inducing damages corroborate the results reported for wheat subjected to mechanical damage by cutting [17] and presumably related to the stress undergone by plants at the time of floral differentiation. Similar reason could be attributed to the smallest number of spikelets obtained when cutting was done at 28 DAE. Under this circumstance, the plant was close to the stage of floral differentiation and was not able to perfectly recover.

The execution times of the damages did not promote a reduction in grain yield under any of the damage methods, except for cutting at 28 DAE. Comparatively, cutting was inferior to the kneading at all induction times, except at emergence.

Table 5. Grain yield values (kg ha^{-1}) at 13% moisture as a function of methods and induction time of mechanical damages in wheat cultivar 'CD 107'

Induction times	Method	
	Kneading	Cutting
Emergence	2,385 Aab	2,446 Aa
7 DAE	2,651 Aa	2,130 Ba
14 DAE	2,596 Aa	2,173 Ba
21 DAE	2,665 Aa	2,151 Ba
28 DAE	2,263 Aab	1,587 Bb
Control	2,453 a	2,453 a
$CV_{(\%)}$	6.87	

DAE: Days after emergence; Means followed by equal letters, upper case in the horizontal and lower case in vertical, do not differ from each other by Tukey test at 5% probability

The difference in productivity between the damaging methods could be related to the larger number of spikes m^{-2}, induced by kneading (Table 3). Cutting resulted greater damage of plants, which severely reduced productivity. In addition to the enhanced damage by cutting could have also been done in a region below the point of growth of the plants, thus promoting abortion of the tines and a subsequent decrease in productivity [18,19]. The effects of damage and elimination of the apical meristem may be more significant in situations of late stress, which would explain the lower productivity when the plants were cut at 28 DAE.

4. CONCLUSION

The mechanical damages caused by the cutting were not beneficial to tillering, development and productivity of wheat at all induction times.

Similarly, kneading did not produce any tillering increase as well as did not increase the productivity.

The results, although not conclusive, demonstrate that the utilization of wheat in an integrated crop-livestock system is promising.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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