Original Research Article

Mechanical Damage in the Tillering, Development and Productivity of Wheat

ABSTRACT

Wheat has great economic importance, especially ~~to~~ in the Southern states of Brazil, ~~being~~ where it is used as an alternative ~~to~~ in the winter period. The aim of this study was to evaluate the effect of mechanical damages in the induction of tillering, development and ~~plants~~ productivity of wheat. Treatments were two methods of mechanical damages (kneading and cutting) combined with five induction times 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 damage caused by cutting method did not provide positive effects in the tillering, development and productivity of wheat grain in any induction time of the cutting. The kneading method did not produce any increase of tillers and productivity, but this method also did not decrease the number of tillers and productivity. The results, despite ~~of~~ not being conclusive, demonstrate to be ~~promising the utilization of~~of the potential of cultivating wheat in an integrated crop-livestock system.

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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 ~~of~~ for winter cultivation. The states of Paraná and Rio Grande do Sul are responsible for more than 85% of the national production [2].

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

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

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

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In ~~plant of~~ winter wheat, the American state of Wisconsin recommends an increase ~~of the~~in plants population from 1.300.000 to 1.750.000 plants per acre when the plant is performed later, due to the lower tillering of wheat when low temperatures reach the wheat in previous phases to the beginning of tillering [9]. Thus, a positive effect is observed ~~of~~ under ~~the~~ cold temperatures on the increase of tillering. This effect is the resulted ~~from~~ of breaking apical dominance, caused by low temperatures, which consequently stimulates ~~the~~ tiller is formation.

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The defoliation causes mechanical stress in the plant due to the removal of leaf~~ area~~, 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 and induction times of damages in the induction of tillering, development, and productivity of wheat~~ plants~~, replacing the low temperatures which occur in winter wheat~~ plants~~, since in some years and regions did not occur enough low temperatures for stimulating a higher wheat tillering.

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2. MAT~~H~~ERIALS 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~~ Marechal Cândido Rondon, localized~~ located at Linha Guará (24°33' of latitude S, 54°04' W of longitude W and altitude ~~of~~ 420 m a.s.l.).

~~The sowing~~ Sowing was ~~performed~~ done mechanically in April using a seeder-fertilizer. The chosen area had already been ~~conducted~~ prepared under no-tillage system for four years ~~on~~ under ~~the~~ soybean residues. ~~The~~ Planting density ~~used~~ was ~~of~~ 300 seeds per square meter, and spacing between lines ~~of~~ 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 ~~treatments culture necessary~~necessary cultural practices were ~~made~~ applied during the ~~performing of~~ the experiment. ~~A top~~Top-dressing fertilizer was ~~performed~~ done at tillering stage, using 40 kg ha^{-1} of N in the form of ammonium sulfate. The plots were constituted by 14 lines ~~with~~ of 5 m~~eters~~ long, totaling 11~~,~~.9 m^2. The useful area of the plot was constituted by six central lines, eliminating 1~~,~~.5 m of each extremity, totaling 2~~,~~.04 m^2.

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The experiment was conducted ~~in~~ with a 2 x 5 + 1 factorial ~~scheme~~design, ~~composed~~ comprising ~~by~~ two ~~methods~~ treatments, namely, ~~of~~ mechanical damages (i.e., plants kneading and cutting) ~~combined~~ and ~~with~~ 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 ~~one~~ a control (no mechanical damages). The experimental design was a randomized complete block with four ~~replicates~~replications.

~~The kneading~~ Kneading and cutting ~~methods~~ were used for artificial induction of mechanical damages. ~~The kneading~~ Kneading ~~method~~ was done by passing a road roller ~~consisted to pass a road roller~~ (Fig. 1A) transversely on the plants of each plot in ~~the~~ a crop row, compressing the plants ~~at~~ to the ground level ~~with~~ at a compaction rate of 0~~,~~.25 kg cm^{-2}. ~~The cutting~~ Cutting ~~method consisted~~was performed by cutting ~~to cut~~ the plants at 2~~,~~.0 cm from the ground (Fig. 1B)~~,~~ using a gardening scissors.

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

~~In~~ The following evaluations were conducted at the end of the experiment~~ was evaluated~~: ~~the~~ tillering as a function of ~~the~~ 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 ~~at~~ on 10 randomly sampled plants ~~randomized~~ in the useful plot. ~~It was also evaluated:~~The following were also evaluated in addition: ~~the~~ final number of spikes per m^2, counting the spikes from 3 lines of 2 meters long ~~of~~ in the useful plot; number of spikelets per spike, counting the number of spikelets formed in each spike; and grain yield (kg ha^{-1}). ~~For this last characteristic~~Grain yield was evaluated ~~the plots were~~by manually ~~harvested~~ harvesting from the plots, ~~manually and the results were converted~~converting total yield per the plot area to kg ha^{-1}, corrected at 13% humidity.

The data ~~were~~ was ~~submitted~~ subjected to analysis of variance, ~~analysis~~ and posterior comparison of means by Tukey's test [12]. ~~All the analyzes were made~~ using Genes software [13].

3. RESULTS AND DISCUSSION

The analysis of variance ~~analysis~~ of the number of tillers per plant ~~in~~ at the end of the ~~experiment~~ study ~~demonstrated~~ revealed that there was ~~not~~ no significant ~~statistics~~ statistical interaction between the ~~method of~~ mechanical damages and induction time. However, significant difference was observed between the ~~There was only significant statistics difference for the method of~~ mechanical damages, ~~showing~~wherein, a higher number of tillers ~~when~~ were recorded ~~the damage was performed by~~after kneading, but it did not differ of the control, no mechanical damages (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 ~~can~~ may be expressive if a commercial ~~crop~~ 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.

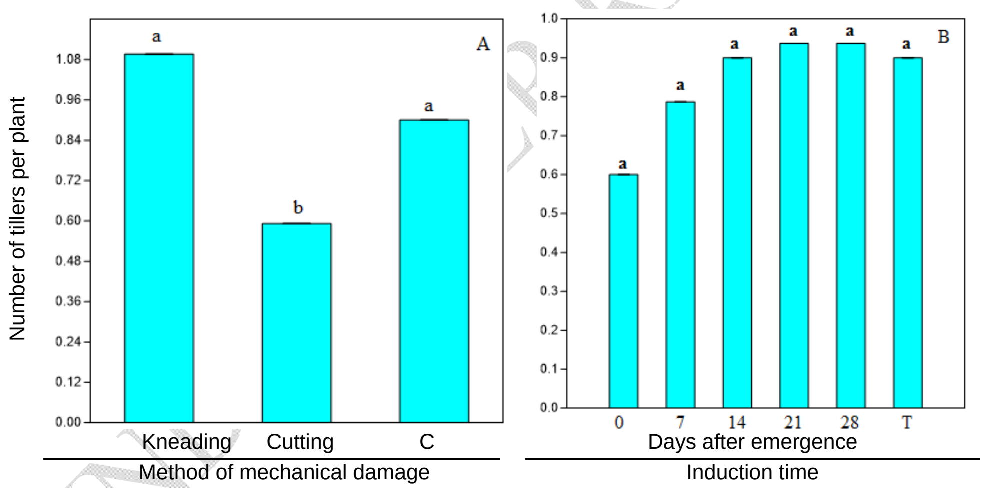

Fig. 2. Final mean number of tillers per wheat plant as a function of methods (A) and induction time (B) of mechanical damages in the wheat cultivar 'CD 107'.

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 ~~by F test~~ (P < 0.05) for all ~~other~~ the ~~characteristics studied~~parameters evaluated in this study. Therefore, nested means were used to ~~study~~ describe each factor within each level of another factor (Tables 1 to 5). It ~~is~~ was observed that the coefficients of variation were less than 10% for the five ~~characteristics, being~~parameters, and were considered low according to the classification of [12], ~~demonstrating~~ showing ~~a~~ good experimental accuracy.

The final height of wheat ~~plants~~ is presented in Table 1. ~~The i~~Induction time of ~~the~~ kneading ~~mechanical damage did not affect~~had no significant effect on ~~the~~ plant~~s~~ heights. However, ~~the~~ cutting ~~method promoted~~ resulted in ~~a~~ significant height reductions ~~when the induction was made from~~at induction times between 7 to 28 days after. ~~The cutting~~ Cutting at ~~the~~ 28 ~~day~~ ~~provided~~ resulted in the

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~~most drastic~~highest production, decreasing the size of the plant by 17.62 cm ~~in comparison to~~ compared to the control. In the comparison ~~of~~ with ~~the~~ induction ~~methods~~, ~~the~~ plants height was ~~inferior~~lower ~~by~~ than ~~the~~ that from cutting ~~damage~~, except when ~~the damage~~it was ~~caused in the~~done at emergence. The results show that ~~the~~ cutting ~~does not present itself as~~is not a beneficial management practice for ~~the plant~~wheat, since ~~the~~ plant height is dependent on the ~~length of the stem~~shoot/stem height, ~~that~~ which functions as a structure for translocation of assimilates, and hence, contributes ~~with~~ to grain filling [14].

Comment [h18]: Do you mean induction times?????

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.

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

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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.

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The final number of spikes per m^2 recorded under ~~did not present a statistically~~kneading was not significantly ~~difference~~ different ~~in relation~~relative to the control ~~when the kneading method was used~~. However, for cutting at 14 and 28 days after emergence (Table 3), there was a significant reduction in the number of spikes/m^2 ~~in relation~~compared to the control.~~, in the treatments performed at 14 and 28 days after emergence (Table 3)~~. The time (plant age) ~~which the~~of cutting ~~was made maybe~~ could have ~~caused~~ resulted in weakening the plants ~~to weaken~~, causing ~~the plants death~~plant senescence at 14 days, and abortion of tillers at 28 days after emergence. This ~~characteristic~~ ~~becomes~~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~~, increasing the productivity~~ [15,16].

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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.

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~~In the methods comparison, the~~ Comparing the two forms of mechanical damage, kneading ~~showed~~ resulted in a higher number of spikes per m^2~~, when the induction was done~~ at 14, 21 and 28 days after emergence (Table 3). These results are similar to those reported for four different cultivars, ~~submitted~~ subjected to ~~the~~ cutting or non-cutting management practices, ~~in which~~wherein ~~the~~ cutting ~~presented~~ resulted in ~~a~~ smaller number of spikes [17]. This ~~is due~~resulted from the stress caused by the cutting ~~method~~ as ~~discussed~~ presented earlier.

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The number of spikelets per spike was statistically similar ~~for~~ at all times ~~in the~~under kneading; however, with regard to cutting, they ~~method and had~~ were ~~an inferior~~lower ~~value~~ only when the damage was ~~done~~ caused at 28 days after emergence~~using the cutting method~~. (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.

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The differences between the methods of inducing damages corroborate~~s~~ 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. ~~Analogous~~Similar reason ~~is allowed~~could be attributed to ~~for~~ the smallest number of spikelets obtained when ~~the~~ cutting was ~~performed~~ done at 28 ~~days~~DAE.~~,~~ ~~in~~ Under this circumstance, the plant was close to the stage of floral differentiation and was not able to perfectly recover.

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The execution times of the damages did not promote a reduction in grain yield ~~for~~ under any of the ~~methods~~damage methods, except for cutting at~~the last time (~~28 ~~days)~~DAE.~~, when using the cutting method. In the comparison of the~~Comparatively, ~~induction methods, the~~ cutting was inferior to the kneading ~~method for~~at all ~~periods~~ induction times ~~studied~~, except ~~in the~~at emergence.

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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 ~~difference~~ between the damaging methods ~~can~~ could be related to the ~~greater~~ larger number of spikes per ~~area~~m^2, induced by kneading (Table 3)~~, in addition cutting~~ Cutting ~~produces~~ resulted greater ~~mutilation~~damage of ~~the~~ plants, which ~~can also~~severely ~~affect~~ reduced ~~the~~ productivity. In addition to the ~~mutilation~~ ~~promoted~~ enhanced damage by ~~the~~ cutting ~~method~~, ~~the management itself (cutting) may~~it could have also been done in a region below the point of growth of the plants, thus promoting abortion of the tines, and ~~consequent~~ a subsequent decrease in productivity [18,19]. The effects of ~~mutilation~~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 ~~days~~.

4. CONCLUSION

The mechanical damages caused by the cutting ~~methods do~~ were not ~~not promote beneficial effects in~~ beneficial to tillering, development and productivity of wheat ~~grains in any of execution times~~at all induction times.
~~The kneading~~ Similarly, kneading ~~method~~ 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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