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Effect of grazing intensities and seed furrow openers on corn development and yield in a crop-livestock system

Marcia F Franchin¹, Alcir J Modolo¹, Paulo F Adami^{2*}, Emerson Trogello¹

¹Program of Post-Graduation in Agronomy, Federal Technologic University of Paraná - PPGAG/UTFPR, Via do Conhecimento, km 01, 85503-390, Pato Branco, PR, Brasil

²Professor of the Agronomy course at Federal Institute of Paraná – IFPR Palmas, PR, Brasil

*Corresponding author: E-mail: paulo.adami@ifpr.edu.br

Abstract

Grazing intensity determines both agricultural and livestock production and may shift the crop-livestock system either in a positive or negative direction. High grazing intensity may affect soil physical-chemical and biological traits, affecting a no-tillage system and as a result, reduce crop yields. These effects can be mitigated by the use of a no-till seed planter equipped with different furrow openers that can interact to optimize crop yield. This study aimed to evaluate grazing intensities and seed furrow openers on corn crop development and yield in an integrated crop-livestock system. The experiment was laid out as random block design in a split-plot arrangement with four replications. Black oat + ryegrass grazing intensities were characterized by different pasture sward management, with the entrance of grazing animal at pasture heights of 25, 30, and 35 cm and exit at heights of 5, 10, and 15 cm, respectively. Grazing was a rotational basis with a treatment without grazing as a control. After the grazing period, corn was established using two seed furrow openers (double disc and shank) in the sub-plot level. Soil bulk density was evaluated before and after the grazing period as well as the depth of seed deposition, corn plant development, corn yield components and yield. Soil bulk density increased as grazing intensity increased. Corn yield dynamics were affected by grazing intensity and the type of seed furrow opener.

Keywords: *Zea mays* L, corn yield components, no-till seed planters, pasture management, soil density

Introduction

In southern Brazil, crop-livestock systems play a major role in farm sustainability. Among the system arrangements, dairy farms with animals raised on pasture such as Black oat (*Avena strigosa*) + ryegrass (*Lolium multiflorum*) in rotation with corn (*Zea mays*) and soybean (*Glycine max*) during the summer highlight as a very important production strategy to improve food security and farm income diversification.

Moreover, specialized agriculture over the last century has brought benefits such as food production and affordability, although, at the same time, has led to concerns about environmental degradation and loss of biodiversity. Crop-livestock systems integrate crop and livestock at the farm scale, allowing better crop production when integrated with livestock and vice versa (Maughan, 2009; Hilimire, 2011).

The success of this system depends on the integrated management of its components (soil-plant-animal) which in turn, are dynamic and interact among each other. Several studies have shown many benefits of the crop-livestock system such as improved soil quality, increased yield, greater diversity of foods, improved pest management and greater land use efficiency (Tanaka et al, 2005; Katsvairo et al, 2006; Russelle et al, 2007; Tracy and Zhang, 2008; Hilimire, 2011).

Crop-livestock systems also have challenges and

management of grazing areas can shift the system production, in either a positive or negative direction. High grazing intensity associated with the lack of fertilization determines the magnitude of changes in the physical, chemical and biological soil traits, which can affect the crop-livestock system productivity.

Soil compaction is one of the major problems facing modern agriculture. This process adversely affects soil physical properties such as, bulk density, infiltration rate and penetration resistance (Greenwood and MacKenzie, 2001) and consequently, affects root growth and crop yield. Overuse of machinery, intensive cropping, short crop rotations, intensive grazing and inappropriate soil management has been reported to cause soil compaction (Hamza and Anderson, 2005).

Changes in soil physical properties caused by grazing have received little research attention in comparison with compaction due to cropping (Greenwood and McKenzie, 2001). The depth of trampling-induced soil compaction ranges from 2.5 to 20 cm depth (Hamza and Anderson, 2005) affecting soil physical properties and crop growth, particularly under wet soil condition. The magnitude of trampling effects is related to the pressure exerted on the soil, which is a function of grazing intensity and soil characteristics [texture, organic matter (OM), soil water content (WC)], and soil residue cover.

Maughan et al (2009) reports higher corn crop

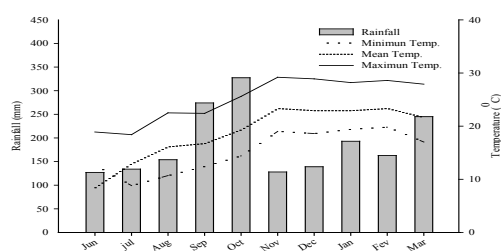


Figure 1 - Average, minimum and maximum temperatures and rainfall data observed through the experimental period (Iapar, 2011).

yield in a crop-livestock system in relation to conventional agriculture. On the other hand, Agostini et al (2012), evaluating crop-livestock systems under no till (NT) reported negative effect on soil physical properties and crop performance, due to the additive effects of reduced soil cover and cattle trampling due to livestock grazing.

Carvalho et al (2011), in a summary about the effects of the grazing intensities (10 years of evaluations), reported that pasture management at 10 cm height adversely affects soil porosity, water infiltration into the soil and the stock of carbon and nitrogen in the soil. Furthermore, aboveground biomass after grazing was not enough to protect soil against erosion and compaction of the soil surface initiating the soil degradation process and affecting yield potential and sustainability of the system.

Soil compaction associated with high grazing intensities can be minimized by the use of No-till planters and drills which must be able to cut and handle residue, penetrate the soil to the proper seeding depth, and establish good seed-to-soil contact, optimizing uniform germination and yield. Among these mechanisms, double disc and shank are the most commonly used due to ability to cut the straw, open a furrow in the soil and deposit the seed and fertilizer to the proper rate, depth and distance (Grisso et al, 2012).

The use of a shank as a furrow opener has been an efficient alternative to minimize soil surface layer compaction, as it mobilizes the soil deeper in the sowing line, improving root and crop development (Unger and Kaspar, 1994), when compared to the double disc furrow opener (Chaudhuri, 2006). This advantage of the shank as a furrow opener has stimulated its adoption, especially in grazed areas (Conte et al, 2011).

This study was designed to address the effects of grazing intensities and seed furrow openers on corn crop development and yield in an integrated crop-livestock system.

Materials and Methods

Research was carried out on a farm at Coronel Vivida, PR (25°07'S and 52°41'W, 730 m altitude). Climate of the region is subtropical humid with well-distributed rainfall throughout the year, according to the Köppen classification and average annual rainfall for the period 1979-2009 was of 2,077 mm year⁻¹ (Iapar, 2011). Soil at the experimental site is classified as an Oxisol (Embrapa, 2006). The meteorological data of the experimental period are shown in Figure 1.

The experiment was divided into two phases and laid out as a randomized block design in a split-plot arrangement with four replications. At the initial phase, different grazing intensities were established on black oat (*Avena strigosa* Schreb) plus ryegrass (*Lolium multiflorum* Lam) at the main plots (184 m²). Pasture sward management was characterized by the entrance of animals to the paddocks at 25, 30, and 35 cm forage height and exit at 5, 10, and 15 cm, respectively, for high, medium and low grazing intensity in a rotational grazing pattern, and one treatment without grazing.

Black oat was sown with a fertilizer-seeder (100 kg ha⁻¹ of seed) on May 5th, 2009 and ryegrass obtained through natural reseeding. Dairy cows (mean live weight of 500 kg) were kept in the paddocks from 5 to 10 hours to establish the treatments. After grazing, ungrazed sites were mowed to uniform pasture height according to the treatment.

After the grazing period (6/27/2009 to 9/16/2009), the area was desiccated (9/17/2009) with 740 g ha⁻¹ of active ingredient of glyphosate, and the main plots were divided into 32 subplots of 23 x 4.0 m (92 m²) with a 1.0 m alley between the plots and 8.0 m between blocks used as a place to steer the tractor and planter and to enhance stabilization of the working speed of the tractor. These sub-plots were used to evaluate two different seed furrow openers (double disc and shank) with the following size: double disc furrow openers were 381 mm (15") in diameter and the shank had a parabolic shape with angle of attack of 20° and tip width of 22 mm.

Corn hybrid Pioneer 30R50 was sown on September 10th, 2009, with a no-till seed drill manufactured by Baldan, model PPSOLO Directa 4000 at a speed of 5.5 km h⁻¹ with row spacing of 0.83 m and a seed density of 60 thousand seeds per hectare or 4.8 seeds per linear meter. A John Deere tractor, model 6110D, 4x2 with a maximum power of 57.4 kW (78 hp) at 2,400 rpm with wheel tires was used to pull the seed drill.

Chemical fertilization was done as recommended by the CQFS RS/SC, (2004), for the expected corn production of 8.0 to 10 Mg ha⁻¹, and according to the values found in soil analyses (0 to 15 cm depth), which were: pH (CaCl₂) 5.3; P = 9.93 mg dm⁻³; K = 0.90 cmol dm⁻³; organic matter = 4.2 g kg⁻¹, Ca = 6.2 cmol dm⁻³; base saturation = 72% and CEC of cmol dm⁻³. A total of 350 kg ha⁻¹ of the chemical formula N-

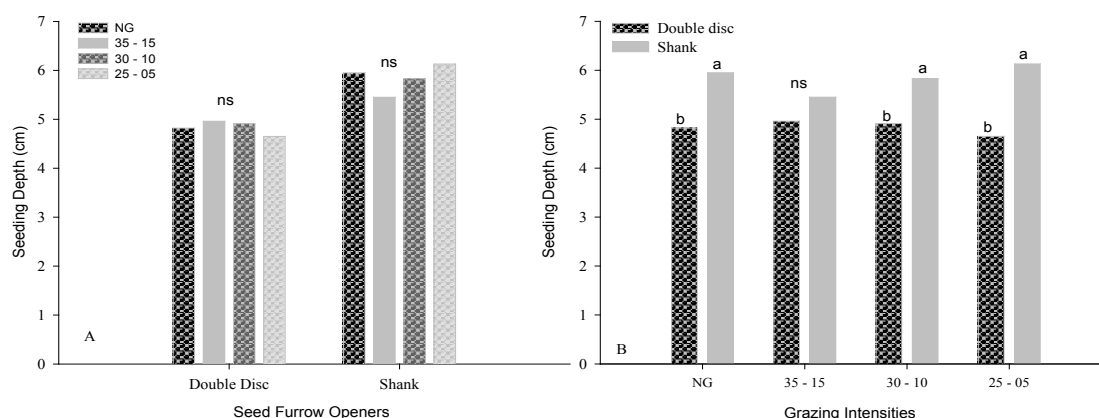


Figure 2 - Seeding depth (cm) at the grazing intensities in relation to furrow openers (A) and at the furrow openers in relation to the grazing intensities (B).

P-K (09-33-12) was applied (31.5 kg ha^{-1} of N, 115.5 kg ha^{-1} of P_2O_5 and 42 kg ha^{-1} of K_2O) at corn sowing time, and 150 kg ha^{-1} of N was split-applied, one half at four-to-six leaf stage (11/11/2009) and the other half at 8 to 12 expanded leaf stage (12/02/2009), according to White and Johnson (2003). Weather conditions and moisture levels were considered to make the best use of N by the system. The nitrogen source used was urea, with a concentration of 45% N.

Soil surface (0 to 10 and 10 to 20 cm) bulk density (kg dm^{-3}) was determined before and after grazing by collecting two soil cores (80.05 cm^{-3}) to each experimental unit according to EMBRAPA (1997) methodology. Seed sowing depth was determined twenty days after sowing in all plots by evaluating 10 plants in each row. With the aid of pruning shears, the corn shoot was cut at ground level, and with a spatula, the part buried in the soil was pulled out and the length from the epicotyl to seed was measured.

Corn plant heights were evaluated at 27 and 86 days after corn sowing by measuring the distance from the ground to the insertion of the corn flag leaf of 14 plants per plot with a ruler graduated in centimeters. Corn yield components were determined by evaluating 25 ears per plot. The number of kernels per row and weight of thousand kernels was assessed by manual counting of 400 kernels. The weight was adjusted to 13% of moisture and its value extrapolated to a thousand-grain weight. To determinate corn yield, three central rows of the sub-plots were hand-harvested, threshed and weighed with a 1.0 g precision balance. Grain production per hectare was subsequently extrapolated, considering the standard 13% moisture content.

Experimental results were subjected to analysis of variance and the means compared by the Tukey test, at 5% probability using the statistical software Statgraphics, 4.1.

Results and Discussion

Soil surface bulk density increased at the grazed treatments when compared to the ungrazed treatment at the 0-10 cm soil layer, indicating that the compaction effects due to animal trampling occurs mainly in topsoil. The significant increase in soil surface bulk density associated with grazing supports results reported from previous research. Greenwood and MacKenzie (2001), evaluating different grazing intensities on the physical traits of an Alfisol under natural grassland concluded that grazing intensities increased soil bulk density in the surface layer, when compared to ungrazed areas. Franzluebbbers and Stuedemann (2008) in a similar work also reported negative grazing effects on soil bulk density. Moreover, Agostini et al (2012) studying different grazing strategies and its influence on corn yield noted a significant difference in soil bulk density in the 0-5 cm soil layer, characterizing surface compaction, similar to the results found by this work.

Figure 2A and B show the results of the seeding depth measurements according to different grazing intensities and seed furrow opener mechanisms, where it is possible to observe the differences between these factors.

Comparing grazing intensities in relation to the seed furrow openers, it is possible to observe there was no significant differences (Figure 2A). However, comparing seeding depth within the grazing intensities (Figure 2B), except for the 35-15 cm treatment, it is observed that the shank provided greater depth of seed deposition in relation to the double disc due to its greater ability to open a furrow in the soil.

This difference becomes even greater at the 25-05 cm treatment, where the depth of seed deposition was 31.5% higher for the shank furrow opener in relation to the double disc. These results are supported by the data found by Chaudhry et al (1990), which reported that shank furrow openers used in the no-till method decrease the soil bulk density in the furrow

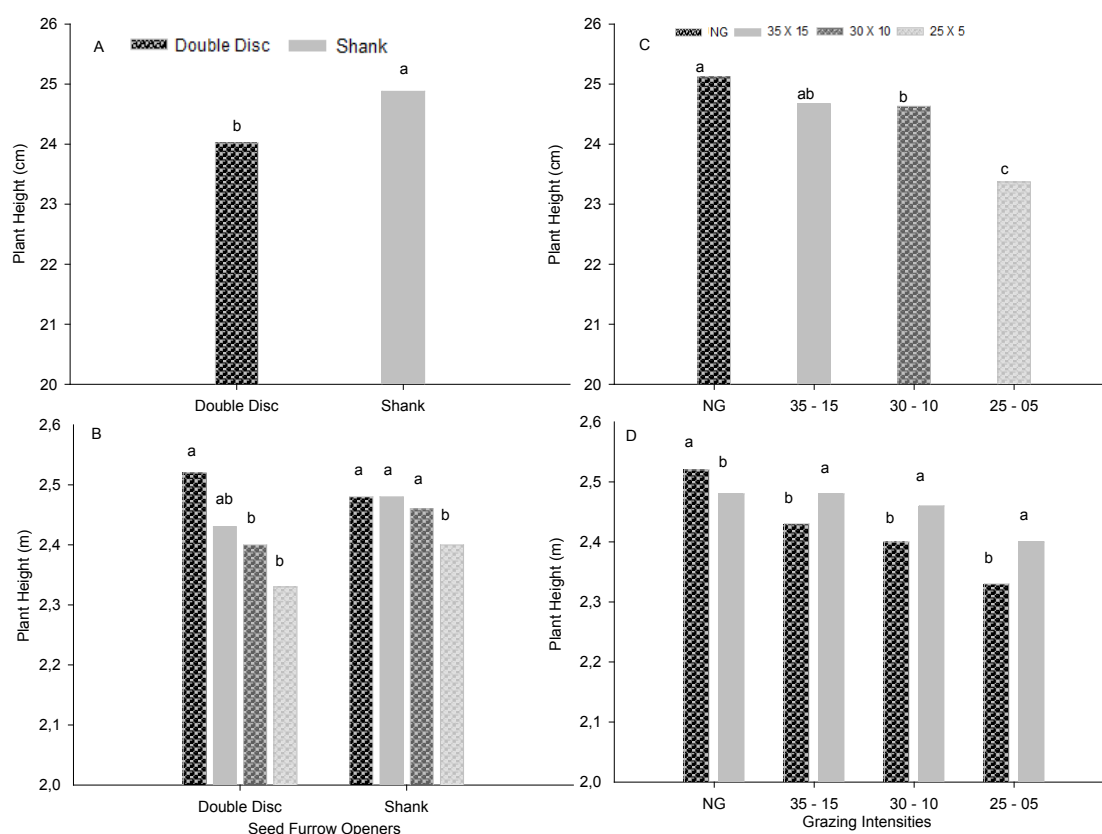


Figure 3 - Corn plant height (cm) 27 and 86 days after corn sowing at the grazing intensities in relation to the seed furrow openers mechanisms (A, B), and the seed furrow openers mechanisms in relation to the grazing intensities (C, D), respectively.

region, and increase oxygen diffusion, in comparison to disc openers. Moreover, Chaudhuri (2001) reported that penetration of furrow openers was a problem in hard soils and disc-type openers did not perform well for zero tillage sowing under stubble mulch conditions due to the tendency of the openers to push dry soil and stubble into the furrows

According to Çelik and Altikat (2013) the depth of seed deposition may affect its germination, being conditioned by temperature, moisture content, seed traits, physical and chemical properties of soil, climate and crop management among other factors. The authors reported that the no-till seeder with a disc type furrow opener achieved better stubble distribution on the soil surface and percentage of seed emergence in comparison to no-till seeder with narrow hoe type openers (shank). Koakoski et al (2007) asserted that the greater the depth of seed deposition, the greater the energy consumption in emergence, in addition to losses caused by low temperatures and low oxygen levels, whereas the shallower the depth, the greater the susceptibility of seeds to water stress.

Regarding plant development, it is possible to observe that the shank seed furrow mechanism provided the greatest initial development of corn plants (Figure 3A). This can be explained by the higher soil breaking capacity and greater depth of seed deposi-

tion provided by this furrow opener (Figure 2A), which may allow better penetration of roots into the soil and at greater depths, which may increase water and nutrients absorption. These results agree with work by Tessier et al (1991).

Considering the grazing intensity effects on plant development, it is possible to observe that the ungrazed and the 35-15 cm treatments had taller plants (Figure 3C). This fact can be explained by the lower soil bulk density values found in these treatments (Table 1), which support and benefit the development of root systems and consequently the absorption of water and nutrients, resulting in a better initial development.

Comparing grazing intensities in relation to the seed furrow mechanisms (Figure 3B), it is noticed that corn plant height (86 DAS) were affected by the grazing intensities at the double disc furrow opener and that these effects decreased as the grazing intensity decreased. Considering the shank seed furrow, it is possible to observe that only the highest grazing intensity (25-05 cm) differed from the other treatments, showing the lowest corn plant height. These results show that the shank mechanism provide better plant development in relation to the double disc mechanism (Figure 3D), although, interference still occurs in plant development.

Table 1 - Mean values of soil bulk density (kg dm⁻³) in relation to different grazing intensities.

Soil Depth (cm)	Condition	Grazing Intensities				CV(%)
		25-5	30-10	35-15	Ungrazed	
0-10	Before-grazing	1.27 a	1.27 a	1.25 a	1.23 a	4.47
	After-grazing	1.37 a	1.39 a	1.35 ab	1.28 b	2.46
10-20	Before-grazing	1.31 a	1.34 a	1.32 a	1.38 a	4.53
	After-grazing	1.28 a	1.41 a	1.35 a	1.39 a	4.81

Means in the same row followed by different lowercase letters differ (P<0.05) by Tukey test.

It can be seen in **Figure 4A**, that the grazing intensities in relation to the seed furrow mechanisms did not affect the number of kernels per row. However, in **Figure 4B**, differences were observed between the furrow mechanisms in relation to the 30-10 and 25-05 cm grazing intensities with the shank mechanism showed higher values. This might be explained by the better plant development, expressed by plant height (**Figure 3**) with the seed shank opener, having consequent greater photosynthetically active area, which may have resulted in a greater number of kernels per row.

Figure 5A illustrates the influence of seed furrow openers on the weight of one thousand kernels. For the double disc seed furrow, there was a linear decrease of weight of one thousand kernels as the grazing intensity increased. For the shank furrow, the 25-05 cm treatment showed the lowest weight, although, it did not differ from the 30-10 and 35-15 cm grazing treatments.

Comparing the furrow mechanisms within the different grazing intensities (**Figure 5B**), it is noticed that there were differences on the 25-05 cm grazing intensity, where the use of the shank provided greater kernel weight when compared with the double disc. However, for the ungrazed treatment, the use of the double disc showed better results than the shank.

Corn yield, shown of **Figure 6A**, demonstrate that for grazed treatments, the double disc opener showed lower yields, with production of 11,026, 10,833 and 10,596 kg ha⁻¹, for the 35-15, 30-10, and

25-05 cm treatment, respectively. Moreover, the ungrazed treatment showed the highest yield (11,537 kg ha⁻¹), producing 940 kg ha⁻¹, or 8.8% more than the 25-05 cm treatment. This difference decreased to 510 (4.6%) and 702 kg ha⁻¹ (6.4%) as grazing intensity was reduced to 35-15 and 30-10 cm. Good weather condition (**Figure 1**) supported high corn yields, even at the highest grazing intensity. The literature has shown (**Bergamaschi et al, 2001**) that the highest yield occurs when rainfall reaches values around 500 to 800 mm during the corn cycle. In dryer years, corn crop yield response may vary more in relation to the treatments evaluated.

It is important to note that these differences are mitigated by the use of the shank seed furrow opener. There was no difference between the ungrazed treatment and 35-15 and 30-10 cm grazing intensities with yields of 11,375; 11,136 and 11,133 kg ha⁻¹ respectively. Although, when compared to the 25-05 cm grazing intensities, the ungrazed treatment showed higher corn grain yields (324 kg ha⁻¹ or 2.9%).

Comparing the seed furrow mechanisms within grazing intensities (**Figure 6B**), there were differences only for the highest grazing intensity (25-05 cm), with the shank more efficient (11,050 kg ha⁻¹) than the double-disk (10,596 kg ha⁻¹). For the other grazing intensities, there was no difference for corn yield in relation to the seed drill used.

Klein and Boller (1995) evaluating corn production with different soil management systems, concluded that the shank furrow type provided better perfor-

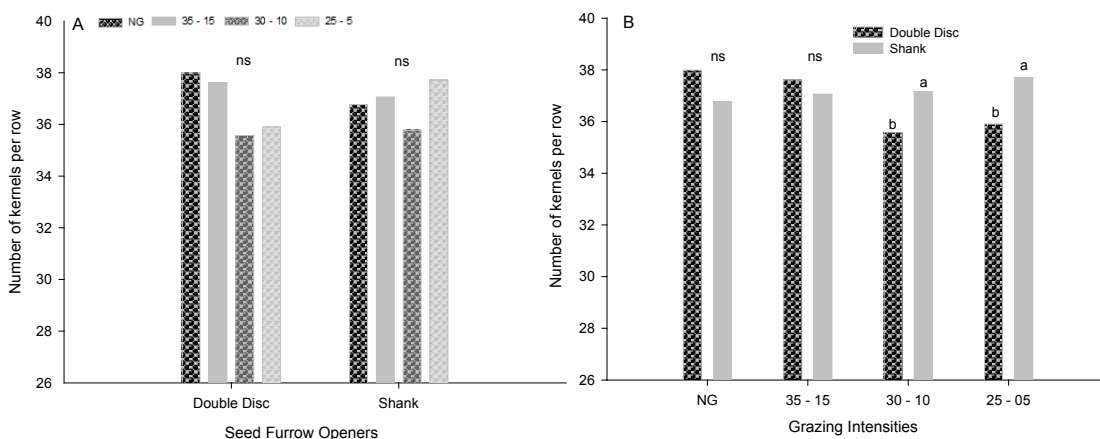


Figure 4 - Number of kernels per row at the grazing intensities in relation to the seed furrow mechanism (A) and for the seed furrow mechanisms in relation to grazing intensity (B).

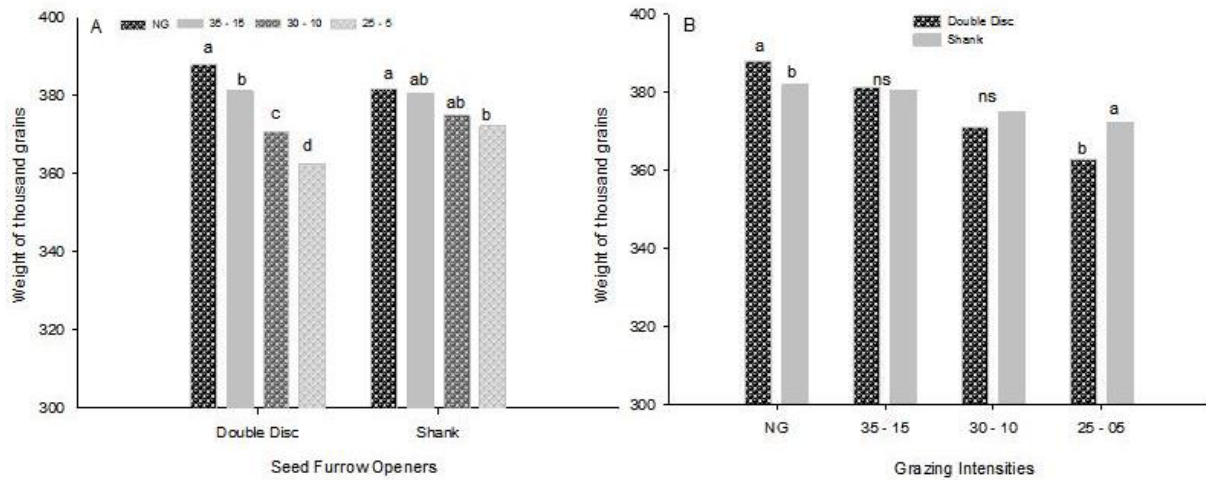


Figure 5 - Weight of thousand kernels (g) by grazing intensity in relation to the seed furrow openers (A) and at the seed furrow openers in relation to the grazing intensities (B).

mance than the double-disc furrow opener and that the use of shank furrow opener eliminates the soil surface compaction problem.

According to White and Johnson (2003), corn plants have their production potential defined during the initial development phase. These authors reported that the initial phase of corn development (up to four leaves) appear to be very important in order to obtain high grain yields. Influence of grazing intensities and seed drills as expressed by height of the plants (Figure 3) interfered with corn yield components and grain yield. Moreover, the authors stated that the number of rows and the number of kernels per row of the corn ear are established before the appearance of the fourth leaf, when the production potential is defined.

Andreolla (2005) also found differences in corn yield with better results for the seed shank furrow opener when compared to the double-disc type, showing that greater depth of seed and fertilizer deposition may benefit the penetration of roots into the

soil to greater depths, which may increase water and nutrients adsorption and consequently increase corn yield.

Mello et al (2003) reported that the shank furrow opener increased corn grain yield by 11.3% compared to the double-disc type. According to the authors, the greater capacity of the shank mechanism to break the soil, reducing the soil density and soil root penetration resistance as well as increased macroporosity explain the higher corn yield found for this seed furrow opener.

It is also noticed in Figure 6A and 6B a tendency to reduce the need to use the shank opener as the grazing intensity decreases, since there were differences only to the highest grazing intensity (25-05 cm). On the other hand, a better response to the double-disc mechanism was observed for the ungrazed areas. Rosa et al (2008) evaluating the influence of two seed furrow openers on corn yield for ungrazed areas reported higher yields for the double-disc in relation to the shank, consistent with this work.

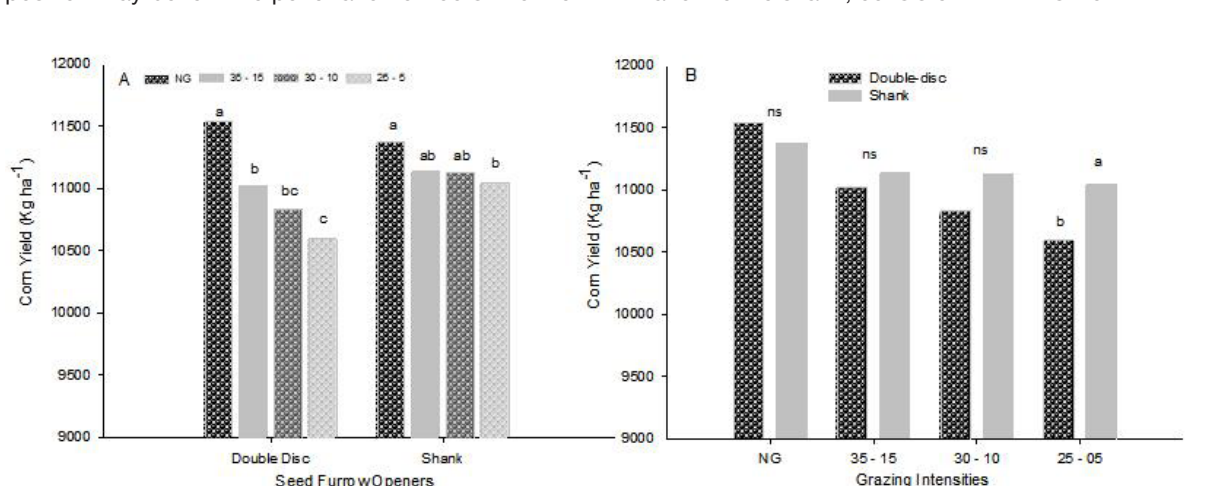


Figure 6 - Corn yield (kg ha⁻¹) at the grazing intensities in relation to the seed furrow openers (A) and at the seed furrow openers in relation to the grazing intensities (B).

Conclusion

Corn yield was affected by grazing intensity in the double-disc treatment. In the shank treatment, there was a significant difference in corn yield between the most extreme grazing treatment and the ungrazed control.

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