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Implantation and biomass of *Avena sativa L.*, two methodologies of preparation, tillage soil and direct sowing

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Abstract: Autumn sowing of oats and other winter species is the alternative to balance the annual dry matter production in Uruguay, with fast forage availability in 60 to 70 days and high nutritional quality. The objective of this research was to evaluate the implantation, biomass production and effect of soil compaction, on the production of oats in two soil conditions, intensive tillage and direct sowing, with two doses of fertilizer, in rain-fed. The experimental design was randomized blocks with 20 repetitions of 50x10cm for implantation and 18 repetitions of 7x4m, for biomass production. The cultivar used was La Estanzuela 1095a. It was determined: implantation of crop, biomass production and the resistance of soil to the penetration. The germination in tillage soil (TS) and direct sowing (DS), showed 91.7 and 76.6% emergence, respectively. The forage production showed no significant differences between TS and DS. The statistical analysis of the green matter data showed a significant difference between the treatments for the control plots and 50 units of nitrogen. The penetration resistance for the 1 cm^{-2} cone showed significant differences at 15 cm depth, while for the 5 cm^{-2} cone the significant differences were at all depths, with DS being greater. The TS treatment showed lower resistance to penetration, better implantation and greater biomass production.

Keywords: *Avena sativa L.*, rain-fed, intensive tillage, penetrometer.

Implantação e biomassa de *Avena sativa* L., com duas metodologias de preparo, preparo do solo e semeadura direta

Resumo: A semeadura no outono de aveia e outras espécies de inverno é a alternativa para equilibrar a produção anual de matéria seca no Uruguai, com rápida disponibilidade de forragem em 60 a 70 dias e alta qualidade nutricional. O objetivo desta pesquisa foi avaliar a implantação, produção de biomassa e efeito da compactação do solo, na produção de aveia em duas condições de solo, preparo intensivo e semeadura direta, com duas doses de fertilizante, em regime de sequeiro. O delineamento experimental foi em blocos casualizados com 20 repetições de 50x10cm para implantação e 18 repetições de 7x4m, para produção de biomassa. A cultivar utilizada foi La Estanzuela 1095a. Determinou-se: implantação da cultura, produção de biomassa e resistência do solo à penetração. A germinação em preparo do solo (PS) e semeadura direta (SD), apresentou 91,7 e 76,6% de emergência, respectivamente. A produção de forragem não apresentou diferenças significativas entre PS e SD. A análise estatística dos dados de matéria verde mostrou diferença significativa entre os tratamentos para as parcelas controle e 50 unidades de nitrogênio. A resistência à penetração para o cone de 1 cm-2 apresentou diferenças significativas a 15 cm de profundidade, enquanto que para o cone de 5 cm-2 as diferenças significativas foram em todas as profundidades, sendo o

DS maior. O tratamento SD apresentou menor resistência à penetração, melhor implantação e maior produção de biomassa.

Palavras-chave: *Avena sativa* L., sequeiro, cultivo intensivo, penetrômetro.

Introduction

Livestock in Uruguay has natural pastures as the main source of food characterized by the predominance of C4 species with great productive seasonality in spring-summer and autumn-winter, high and low respectively (DIEA, 2018; León et al., 1992). This limitation in the cold months, does not allow meeting the nutritional demands of the animals, considerably affecting the animal production of meat and milk (Rana et al., 2014; Ahmad et al., 2014). Autumn sowing of oats and other winter species is the alternative to lift this limitation and balance the annual production of dry matter, with fast forage availability in 60 to 70 days, of high nutritional quality (Condón et al., 2016; Bilal et al., 2017).

In Uruguay, oats are the second most sowed winter species as green after ryegrass, with an average annual forage production of 8777 kg DM ha^{-1} (Condón et al., 2016; Castro et al., 2018).

The method used in soil preparation affects oat production, where aggregates exert different levels of resistance to root exploration (Ehlers et al., 1983). Reduced tillage can cause a decrease in yields due to the effects of compaction and formation of "plow sole", this layer of soil below the surface reduces root growth (Seehusen et al., 2014; Riley et al., 2005; Hansen et al., 2007).

In Uruguay, the DS has replaced conventional tillage, especially in systems with rotations of crops for grains, due to the advantages it provides to production, such as reduction in soil erosion, intensification of productive systems, etc. (Sawchik, 2001). However, when the soil is not tilled, there are some changes in the distribution of nutrients as well as in the water content of the soil, growth rate, development pattern, morphology and the size of the root system; which could be affecting plant establishment (Bordoli, 2001).

The water and nitrogen deficit are two of the main factors that can restrict crop yields (Neugschwandtner and Kaul, 2014; Passioura, 2002). Vegetative and reproductive growth depends on the application of nitrogen to meet crop demand (Lawlor, 2002). The response of grasses to nitrogen fertilization is determined by the ability to increase the number and / or size of tillers, which has an important seasonal variation, being high in autumn, when plants remain vegetative, and very low in spring, when the reproductive cycle begins (Rebuffo, 1994).

In this context, the objective of this study was to evaluate the implantation, biomass production and compaction effect on oat production in two soil conditions, intensive tillage and SD, with two doses of fertilizer rain-fed.

Materials and methods

The trial was made between April and December in 2019, in the experimental area of the Faculty of Agronomy (EEFAS), located on National Route 31, km 21, next to San Antonio´s town, Department of Salto in Uruguay, in the coordinates geographical latitude 31º22'31,4 "S, longitude 57º43'3,2" W, altitude 90 m.s.n.m. The climate in the region is classified as humid subtropical, denominated (Cfa), according to the system of classification of Köppen

(1928). The average annual values of the parameters: precipitation, average temperature and relative humidity are 1322mm, 18.1 and 72%, respectively. The minimum and maximum monthly rainfall in the season was 67 and 150 mm month^{-1}, in the months of July and November, respectively. In the study period, the mean, maximum and minimum reference evaporation were 2.41; 8.1 and 0.3 mm d^{-1} respectively (Figure 1).

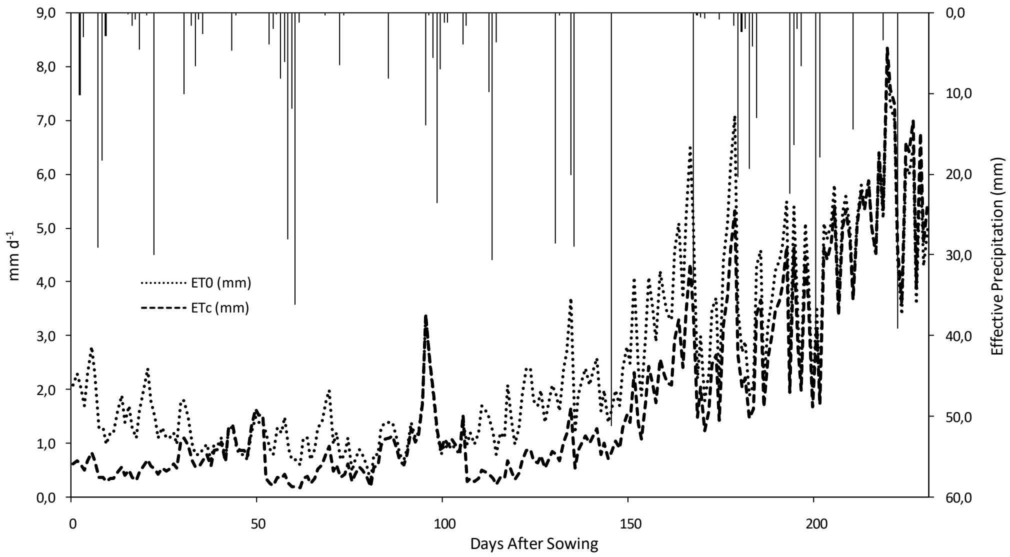

Figure 1. Climogram for the trial period, Salto Uruguay.

The experimental design was randomized blocks with 20 repetitions of 50x10cm for implantation and 18 repetitions of 7x4m, for biomass production. The cultivar used was La Estanzuela 1095a, widely used in the region, with the following characteristics: germination 85 and purity 98%.The sowing was carried out on April 17th, employee seeding model SEMEATO, with 13 planting lines, separation of 0.17m and depth of 3cm, planting density of 75 kg ha^{-1}. Fertilization was applied superficially at 49 and 110 days after sowing (DDS) according to the soil analysis and the test treatments were divided into 25 and 50 units of N ha^{-1} and control plots (without fertilizer) for the 18 repetitions.

The predominant soil in the area is typical Brunosoleutricoof the soil unit Itapebí - TresÁrboles, according to the classification proposed by the Soils and Fertilizers Direction of the MGAP (1976) for the soils of Uruguay. The physical and hydric parameters of the soil are shown in (Table 1).

Prior to the installation of the experiment, the soil was prepared for the treatment with TS with three passes of chisel in different directions, an eccentric disc pass and a tooth harrow pass, guaranteeing the homogeneity of the soil. For the DS treatment, herbicide, 3 L ha^{-1} Glyphosate and 1.5 L ha^{-1} 2.4D Amina were applied to eliminate broadleaf weeds.

Determinations: crop implantation, estimating quotient between the number of seedlings and the number of seeds planted. The number of seedlings was determined by counting in ten samples per experimental unit of 50 × 10cm, in fixed zones at 6, 12, 19 and 27 DAS (Hay et al., 2000). For the estimation of the number of sowed seeds, the count and weight of

1000 sowed seeds/m^2 was made, from the sowing density, seed weight, percentage of germination and purity, in 4 samples with 6 repetitions. The yield of forage was estimated by using a rotary bag collector (Honda HRC216HXA), cutting at 105 DAS a 0.53 × 5m sample in each plot, leaving a 5 cm high remnant so as not to compromise the regrowth of oats. Then, the pasture harvested per plot was weighed and a subsample of 50g in each was extracted, which was taken to a forced air oven (Labtech) at 60 ° C for 48 h until it reached constant weight. To determine biomass production, at 49 and 96 DAS, 3 plants were extracted per plot, the aerial part and roots were weighed and measured separately, in a fresh condition, and dried after placing them in an oven until they reached a constant weight.

Table 1. Granulometric composition and hydric parameters of the soil.

Depth (cm)	Texture (%)			Water parameters of the soil	
	Sand	Clay	Silt	FC (% Hv)	PWP (% Hv)
0-20	22.1	45.5	32.4	37.53	30.56
20-42	20.6	50.8	28.6	40.54	32.79
42-65	19.6	55.7	24.7	40.59	32.22

FC: Field Capacity, PWP: Permanent Wilting Point.

Penetration resistance was determined using an Eijkelkamp penetrometer with 1 and 5 cm^{-2} cones, with monthly measurements from day 13 to 184 DAS, at 5, 10 and 15 cm depth with 3 repetitions per plot.

The statistical analysis was a multiple comparison of means by the Tukey method with a probability level of 1 and 5% ($P \leq 0.01$, $P \leq 0.05$). Data processing was carried out with InfoStat software.

Results and discussion

The number of established plants is shown in (Table 2). The average weight of 1000 seeds, before sowing, was 23.4 g with a coefficient of variation (CV) of 2.58%. The CV of the number of plants emerged, decreased as the evaluations were carried out, showing less CV at 27 DAS. In all the evaluations the largest number of plants emerged was in the TS treatment and according to the statistical analysis showed no differences at 7 and 12 DAS. At 27 DAS, the implantation in TS and DS, was 91.7 and 76.6% respectively, demonstrating significantly better implantation and development of the plants in TS. This difference could be attributed to better soil moisture retention, higher temperature, aeration and root development, and the latter affected by resistance to penetration. In this sense, the penetration resistance results in (Table 5) show higher values for the plots in the DS treatment and low for TS. The results of establishment are similar to those published in another work, although the gap between treatments in this experiment was smaller, reaching 15.1%, and the CV was also smaller for all evaluations performed (Rodriguez-Padrón et al., 2019).

Table 2. Average number of plants (m^2), establishment of oats.

DAS	Tillage Soil		Direct Sowing		CV (%)
	Plants	(%)	Plants	(%)	
7	8.11ᵃ	50.4	7.67ᵃ	47.6	24.78
12	11.78ᵃ	73.2	9.5ᵃ	59.00	20.59
19	14.33ᵃ	89.0	11.83ᵇ	73.5	15.68
27	14.78¹	91.8	12.33ᵇ	76.66	12.53

Different letters in horizontal order indicate difference (p≤0,05) with the Tukey test.

The forage yield is shown in (Table 3). Dry matter production did not show significant differences, for nitrogen fertilization levels between TS and DS treatments. These results were different from those reached by other researchers where the differences between nitrogen treatments were 12% for the growing seasons 2016-17 and 2017-18 (Kadam et al., 2019). On the other hand, the TS treatment on average produced 222.49 kg ha-1 (20.5%) more than DS, these results are less than consulted works, where the difference between similar treatments was 56% (Rodriguez-Padrón et al., 2019). It was also observed that the TS treatment against DS favored the production in volume per square meter of green material and dry matter. This effect is repeated in other published works and they also found that the yield of oats in TS was double with respect to DS (Seehusen, 2014; Seehusen et al.,2017; Mašek and Novák, 2018).

Table 3. Yield of dry matter (kg ha^{-1}), Salto Uruguay.

N	Tillage soil	Direct sowing	CV (%)
0	227.84ᵃ	162.95ᵃ	15.14
25	361.09ᵃ	313.61ᵃ	21.26
50	497.18ᵃ	387.06ᵃ	15.24

N: Nitrogen units. Letters in horizontal order indicate difference (p≤0,05) with the Tukey test.

The biomass production of the aerial and root part at 49 and 96 DAS, is shown in (Figure 2, 3 and 4). The results showed greater biomass production and plant size in the TS treatment for the 2 doses of nitrogen and the control. Statistical analysis of green matter data (Figure 2), showed significant differences between treatments for control plots and 50 units of nitrogen. The ratios of aerial part and root were greater in the control and 50 units of nitrogen in the TS treatment, while the 25 units showed no difference between the treatments.

The production of biomass from the interaction of the aerial part-root and photosynthesis, the aerial part will be developed so much that the limiting factor is the amount of water incorporated by the roots; on the contrary, the roots will develop until their demand for photoassimilates of the aerial part equals the contribution (Taiz and Zeiger, 2006). This functional balance changes if the water supply is reduced, the ratio of the aerial and root part seems to be governed by the aerial part (Daniel et al., 1982).

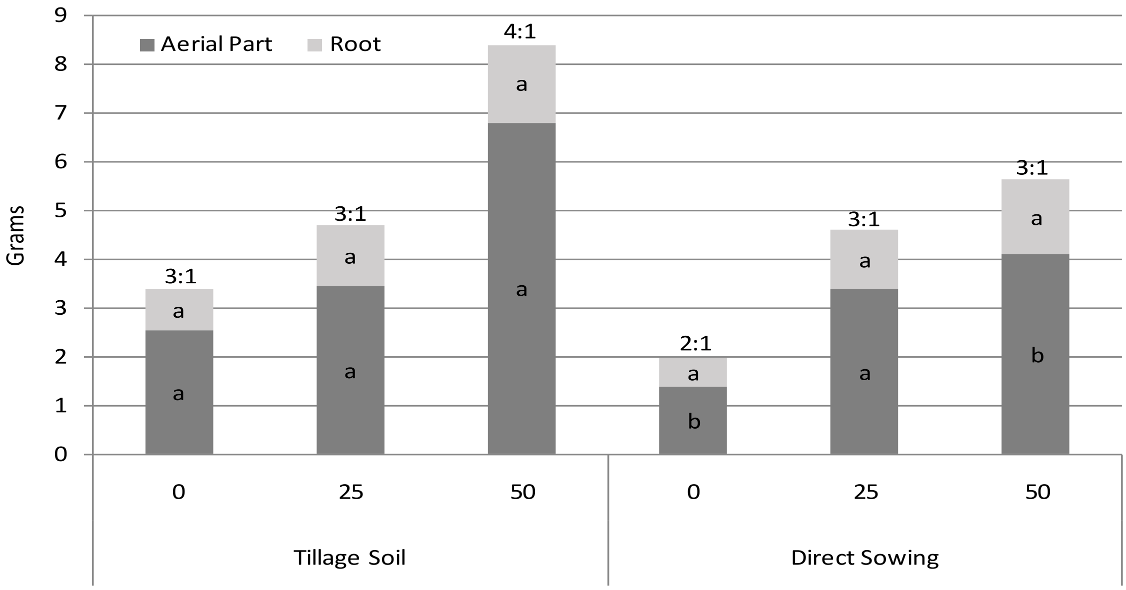

Figure 2. Green matter relation of aerial part and root. Letters in horizontal order indicate difference (p≤0.05) with the Tukey test.

The statistical analysis of the plant length data (Figure 2) gave a significant difference for the aerial part when comparing TS with DS. The ratio of aerial and root part was higher for the plots with 25 units of nitrogen in the TS treatment, but there was no difference for the control plots and the 50 units of nitrogen. The penetration resistance results are shown in (Table 5), at 10 cm the SL treatment gave less resistance, which is not consistent with the biomass results, which could be attributed to the early stages of the process of plow sole formation.

Foliar expansion is rapidly affected by reducing water supply, while photosynthetic activity is less affected. The inhibition of the expansion reduces the consumption of carbon and energy and a large part of the products assimilated by the plants can be distributed by the root system, where they can sustain a later growth, at the same time the root apices lose turgidity in the ground (Hawley and Smith, 1972).

The results of the analysis of dry matter data did not give a significant difference between the treatments. The ratio of aerial and root part was higher for the three cases evaluated in the TS treatment, with respect to DS. This behavior may be due to the fact that according to what some authors mention, in TS, the levels of nitrogen in the soil are significantly higher than in soils with DS (Alvarez and Steinbach, 2009). This greater availability of nitrogen can cause rapid cell division and elongation, which could have favored a greater length of aerial part and contribute to a greater dry matter ratio of aerial and root part (Hasan and Shah, 2000).

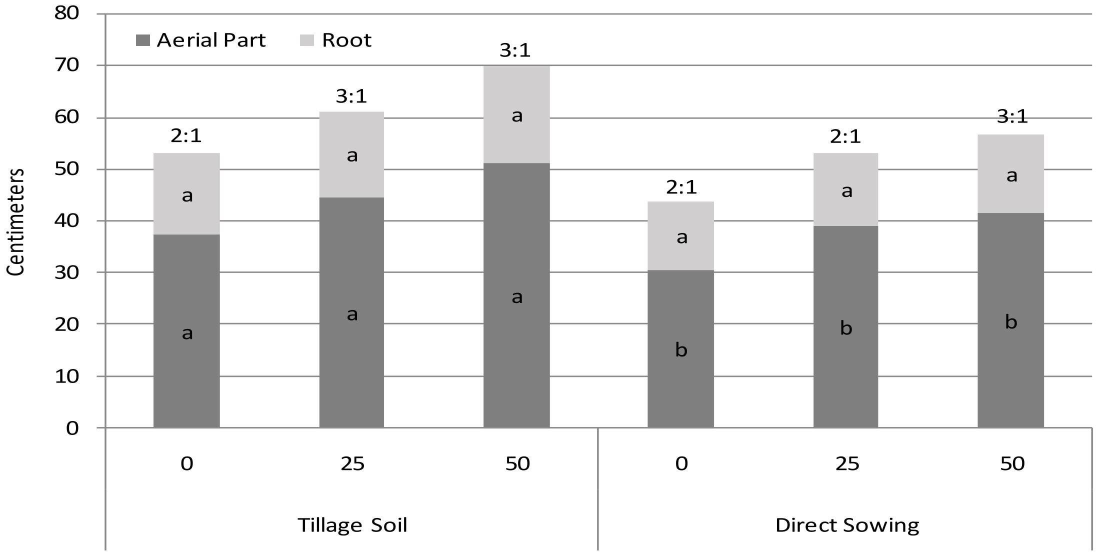

Figure 3. Relationship of the length of aerial part and root. Letters in horizontal order indicate difference (p≤0.05) with the Tukey test.

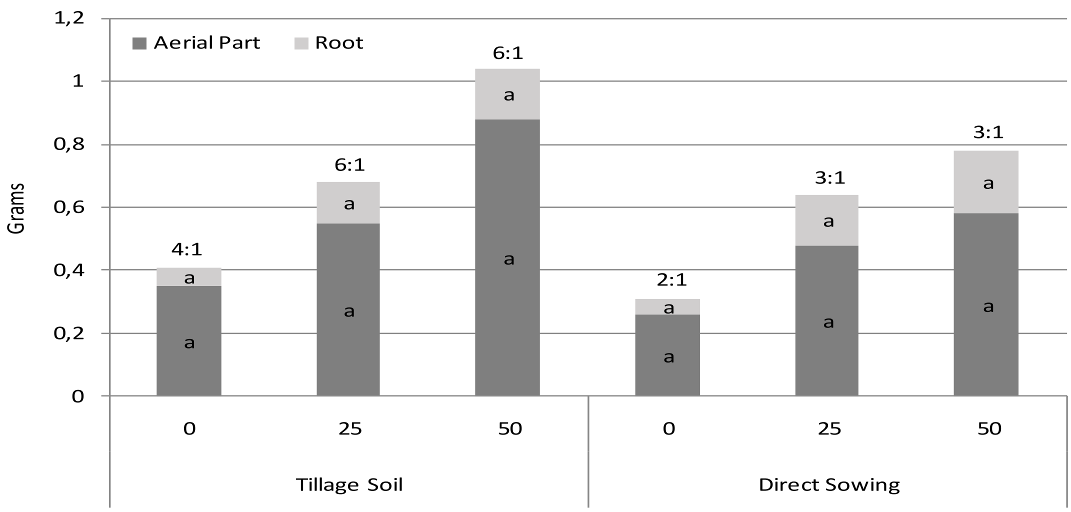

Figure 4. Dry matter relation of aerial part and root. Letters in horizontal order indicate difference (p≤0.05) with the Tukey test.

The analysis of the coefficients of variation of green matter, length plant and dry matter in (Table 4), showed high values for all the aforementioned determinations, the coefficient of variation of plant length gave lower values with respect to the others.

Table 4. Coefficients of variation of samples in the treatments of TS and DS.

Characteristics		CV[1] (%)		
		0	25	50
Green Matter	Aerial Part	51.04	45.1	46.76
	Root	46.43	42.62	53.34
Length Plant	Aerial Part	20.52	12.48	13.44
	Root	23.25	38.99	17.66
Dry material	Aerial Part	56.61	47.02	55.32
	Root	26.46	67.27	70.34

[1] Variation coefficients obtained from the breakdown of the ANAVA for each experiment.

Table 5. Average soil resistance data (Penetrometer).

Depth (cm)	Tillage Soil	Direct Sowing	CV (%)
		Con 1 cm^{-2} (N)	
5	113.33[a]	120[a]	27.77
10	120[a]	126.13[a]	29.31
15	114.84[a]	130.91[b]	26.6
		Con 5 cm^{-2} (N)	
5	180.56[a]	364.94[b]	53.7
10	251.69[a]	489.56[b]	33.2
15	394.67[a]	519.56[b]	25.74

Letters in horizontal order indicate difference (p≤0,05) with the Tukey test.

The average penetration resistance in TS and DS during the period under study are shown in (Table 5). The resistance to penetration with the cone of 1 cm^{-2}, at a depth of 15 cm, showed statistical difference, the DS being greater. At 5 and 10 cm depth, no statistical difference was shown, however in these profiles it shows greater CV. The 5 cm^{-2} cone showed significant statistical difference at all depths evaluated, and the same behavior as the 1 cm^{-2} cone with respect to the CV value, although the highest value was given at 10 and 5 cm for the 1 cm^{-2} and 5 cm^{-2} cones, respectively. In the DS treatment for both cones, it gave greater resistance to penetration at 15 cm. The cone 1 cm^{-2} at 10 cm TS showed a greater resistance to penetration, this result coincides with other published works and is explained by the formation of plow sole (Rodriguez-Padrón et al., 2019). The formation of plow sole is characteristic of heavy soils with agricultural use DS and more than 5 years without being tilled, which partially coincides with the result obtained in this work, since it was performed on a heavy soil but the greatest resistance was given in the TS treatment (Sanzano et al., 2012). Deep vertical tillage is a viable alternative to solve compaction problems. There are numerous options for the decompaction of soils, within the tools, the paratill is more energy efficient than chisel (Ressia, 2010).

Conclusion

The implementation of some agricultural practices in soil management, such as tillage, has improved implantation as well as plant development. In addition to tillage, greater root and aerial production has been achieved, achieving greater development in both cases. These results are in turn accompanied by low resistance to penetration in the SL which would allow to achieve the results obtained.

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