The conditioning of soil, as an agricultural strategy, improves the yield of aerial biomass in oats. The aim of this study is to evaluate establishment, yield of forage and grain production of oat crop in soil conditions with tillage and direct sowing, in rain-fed. The experimental design was random blocks with 6 repetitions for the green biomass plots and 12 repetitions for grain. The experimental plot was constituted by 25 m². The cultivar used was La Estanzuela 1095a. It was determined: establishment of crop, yield of dry matter and grain, dry matter from aerial part and root, and the resistance of soil to the penetration. The germination in tillage soil and direct seed, showed 98.1 and 49% emergence, respectively. The dry matter of the aerial part and root, did not show significant statistical differences. Penetration resistance showed statistical differences in depths 6 and 11 cm, being higher in direct sowing. The yield of dry matter, showed significant statistical differences, being 56% higher on tilled soil. This soil showed less resistance to penetration, better establishment and dry matter yield of oats, offering more biomass for grazing.
The Office of the Directorate of Agricultural Statistics (DIEA) of Uruguay, informs that in 2017 the livestock, agricultural-livestock and dairy production occupied 15,952 thousand hectares, of which 7.5, 4.2, 3.4% represent the area destined to artificial grasslands, improved natural field and annual fodder crops, respectively (DIEA-Yearbook, 2018). The livestock (11.7 million cattle in 2017) has as main source of food natural pastures (DIEA-Yearbook, 2018). These natural pastures are characterized by the predominance of C4 species, which generates high seasonal variability in the production of forage with maximum production in spring-summer (León et al., 1992), therefore, it is difficult to cover the nutritional requirements of animals during the year, obtaining low production of meat and milk (Rana et al., 2014; Ahmad et al., 2014). In this sense, the production of forage species constitutes the backbone of livestock production (Peer, 2015). According to Condón et al., (2016) the sowing of oats in autumn allows to obtain forage in a short period (60-70 days) with adequate quality at time of year where the natural grasslands reduce their contribution (Bilal et al., 2015).

Direct sowing in Uruguay has replaced conventional tillage, generally in continuous crop rotation systems for grain. This method incorporates advantages to the system, decreasing soil losses due to erosion, more flexibility in sowing opportunities, intensification in use of soil, among others (Sawchik, 2001). However, Bordoli (2001), says that when there is no tillage at the soil, it affects the vertical distribution and dynamic of nutrients, similar happens with organic matter, microbial activity and roots of crops. Also, other factors are altered by greater amount of organic waste on the surface, protecting the soil from solar radiation, increasing infiltration, resulting in low rates of evaporation, aeration and temperature, with an increase in soil moisture and density. In addition, lower soil temperature retards the germination and initial growth of crops, as well as size of root systems.

Decomposition of stubble in coverage and the wash of organic acid residues, accompanied by the nitrification of possible ammonia fertilizers, could produce an acid layer (1 to 5 cm thick) on the surface of mineral soils under these conditions (Bordoli, 2001).

According to Zerbino (2001), the method of direct sowing and presence of stubble creates an environment conducive to the proliferation of individuals that live in the soil, which are characterized by slow movements, low reproduction rate and long biological cycles. It is the case of white worms, wire worms, crickets, weevils and other groups that are not insects such as slug, snail and little bug. High populations of these individuals are a consequence of previous management and not of the crop in which they are causing damage. But it also favors the survival of natural enemies and biological control. The trend is the restoration of the native fauna, where insects classified as pests, happen to be in balance with the environment, performing beneficial functions for the whole system.

In this context, the aim of this study was to evaluate the establishment, yield of forage and grain production of the oat crop in soil conditions with tillage and direct sowing, under rain-fed.

Materials and methods

The trial took place between March and December in 2018, 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 31°22’31.4”S, longitude 57°43’3.2” 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-Geiger. The average annual values of the parameters: precipitation, average temperature and relative humidity are 1322 mm, 18.1°C and 72%, respectively. The minimum and maximum monthly
rainfall in the season was 36 and 347 mm month\(^{-1}\), in the months of June and May, respectively. In the study period, the mean, maximum and minimum reference evaporation were 2.95; 7.2 and 0.4 mm d\(^{-1}\) respectively (Figure 1).

The experimental design was random blocks with 6 repetitions for the green biomass plots and 12 repetitions for grain. The experimental plot was constituted by 25m\(^2\). 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 4, employee seeding model SEMEATO, with 13 planting lines, separation of 0.17 m and depth of 3 cm, planting density of 70-80 kg ha\(^{-1}\). Fertilizer was applied superficially considering the soil analysis, at 33 and 130 days after sowing, applying 100 kg of N ha\(^{-1}\).

The predominant soil in the area is typical Brunosol eutrico of the soil unit Itapebi – Three Trees, according to the classification proposed by the Soils and Fertilizers Direction of the MGAP (1976) for the soils in Uruguay. The physical and hydric parameters of the soil are shown in (Table 1).

Prior to the preparation of the soil, the stubble of soybean was cut throughout the experimental area. Later, in the preparation of soil with tillage, a

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**Table 1.** Granulometric composition and soil water parameters.

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Texture (%)</th>
<th>Water parameters of the soil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Silt</td>
<td>Clay</td>
</tr>
<tr>
<td>0-20</td>
<td>22.1</td>
<td>32.4</td>
</tr>
<tr>
<td>20-42</td>
<td>20.6</td>
<td>28.6</td>
</tr>
<tr>
<td>42-65</td>
<td>19.6</td>
<td>24.7</td>
</tr>
</tbody>
</table>

FC: Field Capacity, PWP: Permanent Wilting Point.
subsoiler pass was done, two eccentric disc passes and a tooth harrow pass, guaranteeing the homogeneity of the soil.

Determinations: establishment of crop, 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 × 10 cm, in fixed zones at 7, 13, and 20 days after sowing (Hay et al., 2000). For the estimation of the number of sowed seeds, the count and weight of 1000 sowed seeds/m² was done in 4 samples with 6 repetitions. Taking into account the sowing density, seed weight, percentage of germination and purity. The yield of forage was estimated by using a rotary bag collector (Honda HRC216HXA), cutting a 0.53 × 5 m sample in each plot, leaving a remaining of 5 cm. Then, the pasture harvested per plot was weighed and a subsample of 50 g in each was extracted, placed in an oven at less than 60ºC to obtain the dry matter portion. 56 days after sowing, 6 whole plants were extracted per plot. The roots were separated from the aerial part and both components were weighed and placed in an oven at less than 60ºC to obtain the dry matter portion. 56 days after sowing, 6 whole plants were extracted per plot. The yield of forage was estimated by using a rotary bag collector (Honda HRC216HXA), cutting a 0.53 × 5 m sample in each plot, leaving a remaining of 5 cm. Then, the pasture harvested per plot was weighed and a subsample of 50 g in each was extracted, placed in an oven at less than 60ºC to obtain the dry matter portion. 56 days after sowing, 6 whole plants were extracted per plot. The roots were separated from the aerial part and both components were weighed and placed in an oven at less than 60ºC. In addition, soil resistance to penetration was estimated with the manual penetrometer method (Eijkelkamp), using cones (1 and 5 cm²) at depths of 6, 11 and 16 cm, with 12 repetitions per plot, at 56 and 66 days after sowing. The grain yield was determined 250 days after sowing, collecting 12 samples per plot per 1m². Subsequently, grains were separated from the biomass to obtain a subsample of grains for the counting of 4 groups of 1000 grains, for each sample collected and to carry out the weighing.

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

Results and Discussion

The number of established plants is shown in Table 2. The average weight of 1000 seeds, before sowing, was 27.85 g, with a coefficient of variation (CV) of 4.27%. The CV of the number of emerged plants decreased as the evaluations were carried out, showing less CV at 20 days after sowing (DAS). In evaluations, the greatest number of emerged plants was in treatment of tilled soil and according to statistical analysis showed no difference to 13 DAS. At 20 DAS, the implantation in tilled soil and direct sowing was 98.1 and 49% respectively, demonstrating significantly better establishment and development of plants in tilled soil. This difference could be attributed to better soil moisture retention, higher temperature, aeration and root development. Willenborg et al., (2005), conclude that there are genotypes and sizes of seeds that behave differently in humid soils. Some genotypes have a better percentage of germination in the range of osmotic potential studied (0, -0.2, -0.4 MPa), because vigor of seeds frequently improves in field condition compared to laboratory analysis.

The dry matter of aerial part and root at 56 days after sowing, is shown in Table 3. The statistical analysis showed no significant difference in variables evaluated. However, the highest percentage of dry matter was shown by treatment in tilled soil. Additionally, the CV in aerial part showed greater variability, in comparison to roots.

The average resistance to penetration in tilled soil and direct sowing at 56 and 66 days after sowing, are shown in Table 4. The resistance to penetration with cone 1 cm², in depths of 6 and 11 cm, showed statistical differences, being higher in direct sowing. In 16 cm of depth, the results showed no statistical difference, however, in this sample profile the CV was higher. The cone 5 cm² showed the same behavior as cone 1 cm², however, in sample profile of 6 cm, it showed higher CV. In direct sowing treatment for both cones, the highest resistance to penetration was at 11 cm. This effect could be related to the formation of "plow sole" (progressive compaction). According to Sanzano et al., (2012) the formation of a plow sole is characteristic of heavy soils, with agricultural use in direct sowing.
and more than 5 years without being tilled. Deep vertical tillage is a viable alternative to solve the problems of compaction. There are numerous decompactant options, Ressia (2010) concludes that the decompaction of soils in direct sowing with paratill is more energetically efficient than with a chisel. Decompacted work, by means either of the chisel or the paratill, performed on a soil with a history in direct sowing, improve the physical properties of soil: bulk density and resistance to penetration.

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

<table>
<thead>
<tr>
<th>DAS</th>
<th>Tilled soil Plants (%)</th>
<th>Direct sowing Plants</th>
<th>DAS</th>
<th>Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>2.4 a 17.8</td>
<td>1.0 b 7.4</td>
<td>76.36</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>5.9 a 43.8</td>
<td>2.8 a 20.8</td>
<td>70.80</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>13.2 a 98.1</td>
<td>6.6 b 49.0</td>
<td>44.29</td>
<td></td>
</tr>
</tbody>
</table>

DAS: Days after sowing.
Different letters in horizontal order indicate difference (p≤0.05) with the Tukey test.

**Table 3.** Dry matter of the aerial parts and roots at 56 days after sowing in oats.

<table>
<thead>
<tr>
<th></th>
<th>Tilled soil (%)</th>
<th>Direct sowing (%)</th>
<th>CV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerial part</td>
<td>15.94 a</td>
<td>13.64 a</td>
<td>10.65</td>
</tr>
<tr>
<td>Roots</td>
<td>15.15 a</td>
<td>15.00 a</td>
<td>6.96</td>
</tr>
</tbody>
</table>

Letters in horizontal order indicate difference (p≤0.05) with the Tukey test.

**Table 4.** Average soil resistance data (Penetrometer), at 56 and 66 days after sowing, in the oat crop.

<table>
<thead>
<tr>
<th>Deph (cm)</th>
<th>Tip number 1, unit of measure N</th>
<th>Tip number 4, unit of measure N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tilled soil</td>
<td>Direct sowing</td>
</tr>
<tr>
<td>6</td>
<td>180.00 b</td>
<td>336.30 a</td>
</tr>
<tr>
<td>11</td>
<td>185.00 b</td>
<td>350.00 a</td>
</tr>
<tr>
<td>16</td>
<td>185.00 a</td>
<td>250.00 a</td>
</tr>
<tr>
<td>6</td>
<td>103.33 b</td>
<td>366.70 a</td>
</tr>
<tr>
<td>11</td>
<td>150.00 b</td>
<td>508.33 a</td>
</tr>
<tr>
<td>16</td>
<td>293.33 a</td>
<td>480.00 a</td>
</tr>
</tbody>
</table>

Letters in horizontal order indicate difference (p≤0.05) with the Tukey test.

**Table 5.** Yield of dry matter and oat grain, in town of Salto Uruguay.

<table>
<thead>
<tr>
<th></th>
<th>Dry matter (kg-DM/ha)</th>
<th>CV (%)</th>
<th>Grain (kg-DM/ha)</th>
<th>CV (%)</th>
<th>Grain (kg-DM/ha)</th>
<th>CV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tillage soil</td>
<td>849.21$^a$</td>
<td>8.7</td>
<td>26.12</td>
<td>8.68</td>
<td>20.86$^a$</td>
<td>8.56</td>
</tr>
<tr>
<td>Direct sowing</td>
<td>478.92$^b$</td>
<td></td>
<td>26.25</td>
<td>7.55</td>
<td>21.64$^a$</td>
<td></td>
</tr>
</tbody>
</table>

Letters in horizontal order indicate difference (p≤0.05) with the Tukey test.
The yield of forage in dry matter and oat grain is shown in Table 5. The yield of dry matter showed significant statistical differences, being 56% higher in tilled soil, differentiated approximately in 370 kg DM ha⁻¹. However, in the grain yield, there were no statistical differences, being 3.6% higher direct sowing treatment. The temperature and humidity in grain were similar. Seehusen et al., (2014) comment that reduced tillage can cause reduction in yields due to the effects of compaction of a layer of soil below the surface. Moreover, Riley et al., (2005) and Hansen et al., (2007) mention that reduced tillage decreases root growth. In a research conducted between 2013-2017 by Mašek and Novák (2018), they observed that conventional tillage favored the production of stems per square meter in oat versus no-tillage, mentioning that this increase in the number of stems to be an important component, produces a greater performance. This effect was repeated in all the evaluated years. These beneficial results of conventional tillage on oat production were also repeated in other research carried out by (Riley et al., 2005; Neumann et al., 2007 and Seehusen et al., 2017).

Conclusion

The use of agricultural techniques and strategies, such as soil tillage, improves yield conditions of aerial biomass in oats, offering more than 50% of biomass for grazing. Soil with tillage showed less resistance to penetration in the first centimeters and better implantation and dry matter yield of oats. However, showed no statistical differences in grain yield under tillage soil conditions.

Conflict of Interest

The authors have not declared any conflict of interest.

Acknowledgements

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