Acta Iguazu
ISSN: 2316-4093

Chlorophyll concentration and grain production *in Avena sativa L.* with two rates of nitrogen fertilizer

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Artigo enviado em 13/05/2021, aceito em 14/06/2021

Abstract: The productive potential of a crop can be known by indirect measurements of the chlorophyll content. The objective of this research was to evaluate the chlorophyll content and the grain production of the oat crop, in direct sowing, with two doses of rainfed nitrogen and a control without added fertilizer. The experimental design used was randomized blocks with 12 repetitions for grain yield. The size of the plot was 25 m^{-2}. The cultivar used was Estanzuela 1095a and 2 different doses of N were used (25 and 50 kg ha^{-1}). The chlorophyll content in the last fully developed leaf and the grain yield were measured. The results indicated that there were no significant differences in the chlorophyll a and b index as well as there were no differences in the total chlorophyll index and in the ratio of the chlorophyll a / b index. The grain yield and the weight of one thousand grains did not show significant differences.

Keywords: chlorophyll index, *Avena sativa L.*, direct sowing, nitrogen fertilization.

Concentração de clorofila e produção de grãos em *Avena sativa L.* com duas doses de fertilizante de nitrogênio

Resumo: O potencial produtivo de uma cultura pode ser conhecido por medições indiretas do teor de clorofila. O objetivo desta pesquisa foi avaliar o teor de clorofila e a produção de grãos da cultura da aveia, em semeadura direta, com duas doses de nitrogênio de sequeiro e uma testemunha sem adição de fertilizante. O delineamento experimental utilizado foi em blocos ao acaso com 12 repetições para produtividade de grãos. O tamanho da parcela era de 25 $m^{-2.}$ A cultivar utilizada foi a Estanzuela 1095a e foram utilizadas 2 doses diferentes de N (25 e 50 kg ha^{-1}). Foram medidos o teor de clorofila na última folha totalmente desenvolvida e o rendimento de grãos. Os resultados indicaram que não houve diferenças significativas no índice de clorofila aeb, bem como não houve diferenças no índice de clorofila total e na razão do índice de clorofila a / b. O rendimento de grãos e o peso de mil grãos não são apresentaram diferenças significativas. Palavras-chave: índice de clorofila, *Avena sativa L.*, semeadura direta, fertilização com nitrogênio.

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Introduction

In the world the production of oats (Avena sativa L.) is approximately 22.2 million tons occupying an area of 9.7 million hectares with an average yield of 2300 kg, placing it in sixth place in world cereal production (FAO, 2017). According to Condón et al. (2016) in Uruguay, oats are the second most planted species after ryegrass with an annual forage production of between

6000 to 11554 kg MS^{-1} (Castro et al., 2014).

Livestock in Uruguay has natural pastures as the main source of food (DIEA, 2018) which are characterized by a predominance of C4 species with great productive seasonality with a marked peak of production in spring-summer (León et al., 1992). This situation means that it is difficult to meet the nutritional requirements of the animals during the year, producing a low production of meat and milk (Rana et al., 2014; Ahmad et al., 2014). In this sense, one can think according to Condón et al. (2016) in the use of oats in autumn sowings as an alternative to obtain a rapid delivery of forage in a short period (60-70 days) with an adequate quality at a time of year where natural grasslands reduce their contribution (Bilal et al., 2015).

The water and nitrogen deficit are two of the main factors that can restrict crop yields (Passioura, 2002). In fact Lawlor (2002) mentions that the increase in vegetative and reproductive growth depends on an adequate application of nitrogen. In the same sense, Montalvan (2014) mentions the importance of nitrogen in the growth of the stem, leaves and branches. However, the excessive addition of nitrogen fertilizer can cause negative environmental impacts and can even be detrimental to the oat crop, causing overturning and a higher incidence of pests and diseases (Giles, 2005; Gimenez and Garduño, 2021). Neugschwandtner and Kaul (2014) mention nitrogen fertilization as one of the factors that influences the yield components. In fact Dartora and Floss (2002) mention that nitrogen is expected to have an effect on the number of grains per panicle, increasing it.

To determine the productive potential of a crop, it is enough to know the chlorophyll content of a single leaf indirectly measured by using instruments called chlorophyllometers (Leuze et al., 2018), which in turn would allow correcting nutritional deficiencies in the cultivation (Makino, 2011). In this sense, investigations have been carried out that have tried to demonstrate the correlation between the chlorophyll content of the leaf of a cereal and the chlorophyll readings, as well as between the chlorophyll readings and the nitrogen content in the leaves of numerous crops (Argenta et al., 2001; Jinwen et al., 2009), showing that the chlorophyllometer can be used for these purposes (Jinwen et al., 2009).

For all the above, this work aims to evaluate the chlorophyll content and grain yield of the oat crop with two doses of nitrogen fertilizers in dry conditions in direct sowing.

Materials and methods

The experiment was developed between the months of April and December 2019, in the experimental area of the Faculty of Agronomy, located at the geographic coordinates of latitude 31º22'31.4 "S and longitude 57º43'3.2" W and altitude 90 meters above the level. from the sea on National Route 31 at kilometer 21, in the Department of Salto, Uruguay. The climate of the region is classified as humid subtropical called (Cfa), according to the classification system proposed by Köppen-Geiger. The annual mean values of the precipitation, mean temperature and relative humidity parameters are 1322 mm, 18.1 °C and 72%, respectively. The minimum and maximum monthly mean rainfall in the crop growth cycle was 2.16 mm and 5.01 mm in the months of July and November, respectively. In the study period, the mean, maximum and minimum reference evaporation were 2.41 mm, 8.1 mm and 0.3 mm, respectively (Figure 1).

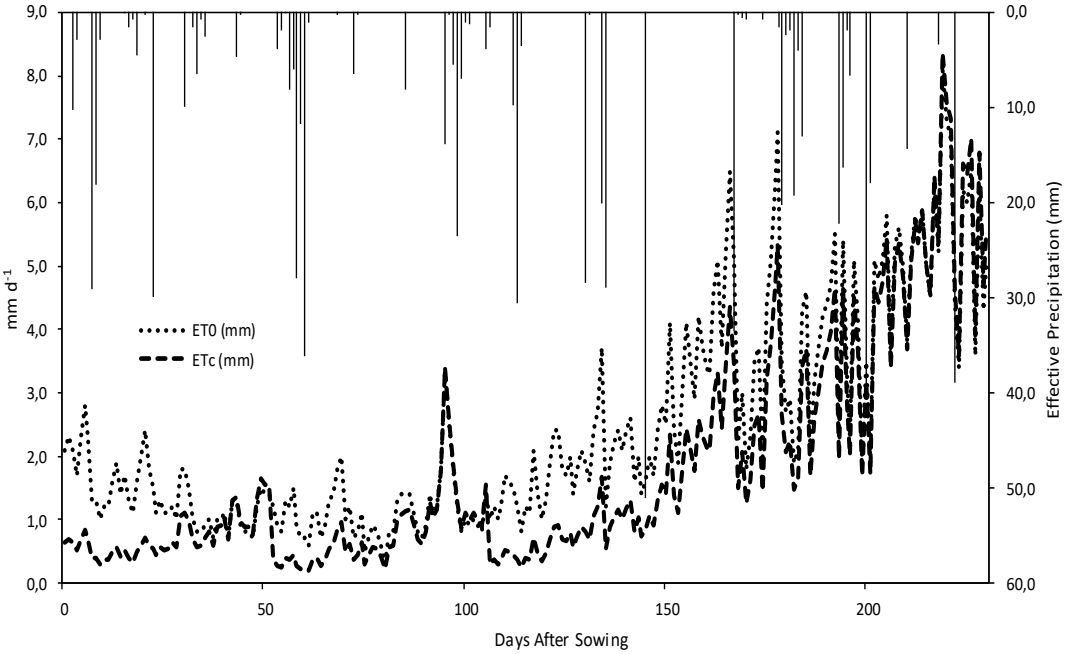

Figure 1. Climogram for the trial period, Salto, Uruguay.

The experimental design was randomized blocks with 18 repetitions of 7 x 5 m. The cultivar La Estanzuela 1095a was used, widely used in the region with 85 and 98% purity and germination respectively. The sowing was carried out on April 17 using a SEMEATO planter, with 13 sowing lines with a separation of 0.17 m between lines and a depth of 3 cm with a sowing density of 75 kg ha^{-1}. The fertilization was carried out according to the soil analysis, adding 2 different doses of 25 and 50 kg ha^{-1} of N, maintaining a plot as a control without adding fertilizer.

The predominant soil is called Typic Hapluderts according to Soil Taxonomy (2014). The physical and hydric parameters of the soil are presented in table 1.

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

Depth (cm)	Texture (%)			Water parameters	
	Sand	Clay	Silt	FC (% Hv)	PWP (% Hv)
0-20	22.1	32.4	45.5	37.53	30.56
20-42	20.6	28,6	50.8	40.54	32.79
42-65	19.6	24.7	55.7	40.59	32.22

FC: field capacity, PWP: permanent wilt coefficient.

Prior to the installation of the experiment, a total herbicide application was carried out with a dose of 3 L ha^{-1} and herbicide to combat broad-leaved weeds with a dose of 1.5 L ha^{-1}. The determination of the chlorophyll concentration was made from the result of the weekly measurements, with chlorophyll measuring equipment (ClorofiLOG® CFL 1030) in three random plants per plot from day 21 to 142 after sowing, in the limb of the last leaf fully unfolded until the appearance of the flag leaf (Falker, 2008). At 230 days after sowing, whole plants were manually harvested at 1 m2 per plot, to

determine grain yield. The grains were then separated from the panicles using a static harvester and 3 subsamples of 1000 grains were counted and weighed for each field sample.

Statistical analysis was performed by multiple comparison of means by Tukey's method with a probability level of 5% (P≤0.05). The data processing was carried out with the R software.

Results and discussion

The results of the analysis of chlorophyll a and b measurements between days 21 to 142 after sowing are shown in (Figure 2). When performing an analysis of the content of chlorophyll a and b, no significant differences were detected for the different doses of nitrogen used (p = 0.279; 0.208 and 0.246 for the chlorophyll a and b index and total chlorophyll respectively).

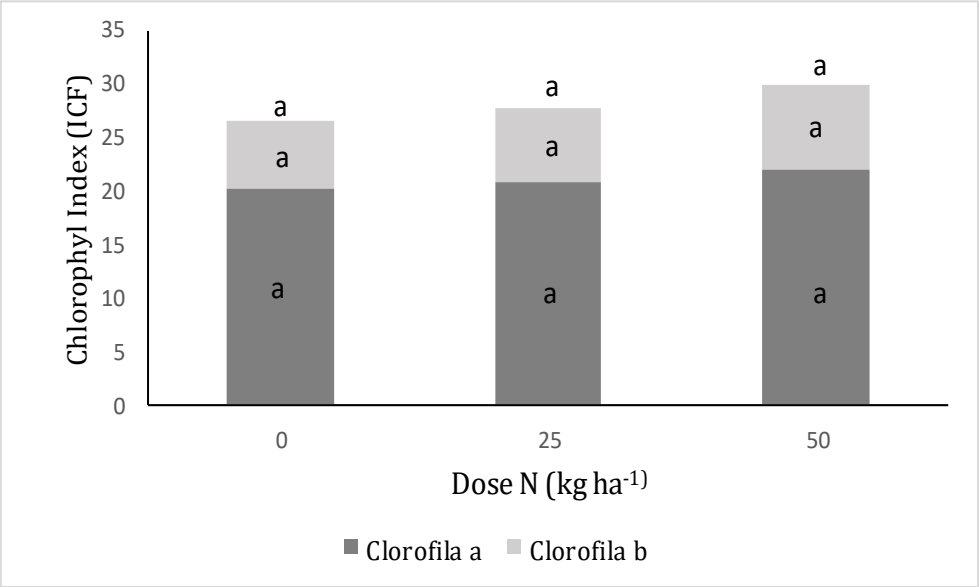

Figure 2. Chlorophyll a and b content of the last fully developed leaf.

Similar results were found by Cancellier et al. (2013) who did not detect significant differences in the chlorophyll b index due to nitrogen fertilization in another type of grass. Total chlorophyll also did not show statistically significant differences according to the nitrogen doses used in this study (Graph 2). Table 2 shows the coefficients of variation for the chlorophyll a, b and total indices. This table shows that the highest coefficients of variation were those of the chlorophyll b index. These higher coefficients of variation according to Cancellier et al. (2013) are due to the greater sensitivity of the parameter to environmental factors such as nitrogen availability.

Table 2. Coefficients of variation (CV%) for the chlorophyll index.

Characteristics	CV (%)		
	0	25	50
Chlorophyl a index	1.5	6.6	7.0
Chlorophyl b index	3.2	8.7	14.1
Total Chlorophyl index	1.1	7.1	8.9

CV (%): coefficient of variation expressed as a percentage.

The ratio of the chlorophyll a / b index is shown in graph 3. This graph shows that no statistically significant differences were found in this relationship (p = 0.234).

In turn, this Figure 3 shows a trend in which the higher the nitrogen fertilization, the lower the ratio of the chlorophyll a / b index. High chlorophyll a / b ratios according to Li et al. (2007), Jinwel et al. (2009) and Cancellier et al. (2013) indicate nitrogen deficiencies, which is consistent with the results of this research. Similar findings were made by Jinwen et al. (2009) who observed lower chlorophyll a / b ratios, the better the nutritional status of the crop leaves, in this case nitrogen-deficient leaves.

The grain yield shown in table 3 did not show significant differences with respect to the nitrogen doses used. Similar results were found by Mantai et al. (2016) and Rodríguez et al. (2019), who did not find significant differences in grain yield in their research using different doses of nitrogen. On the contrary, Ramos and Curbelo (2004) in their research found a significant increase in grain yield as the dose of nitrogen applied increased. Ramos and Curbelo (2004) obtained a grain yield that was 16 and 36% higher than those obtained in this investigation for the control without the addition of fertilizer and the dose of 50 kg ha^{-1} of added nitrogen.

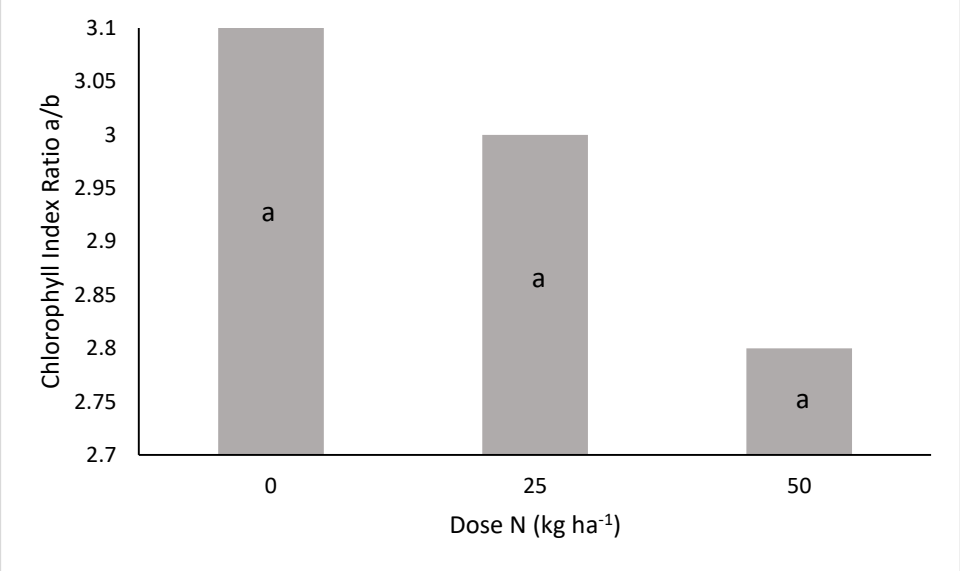

Figure 3. Chlorophyl index ratio a/b.

Table 3. Yield in grain and weight of one thousand oat grains in Salto, Uruguay.

Dose (kg ha^{-1})	Grain yield (kg ha^{-1})	Grain			
		Temp (°C)	Humidity (%)	PMG (g)	CV
0	850 [a]	26.2	8.7	18.5 [a]	
25	952 [a]	26.3	7.5	19.2 [a]	7.6
50	961[a]	26.0	7.8	20.2 [a]	

Different letters show significant statistical differences (P <0.05)
PMG: weight of a thousand oat grains.

The thousand grain weight (PMG) did not show significant differences between the nitrogen doses used in this research. These values were lower than those reported by Rodríguez et al. (2019) which in a similar experiment obtained an average weight of one thousand grains of 21.64 g under direct sowing conditions.

Conclusion

The different doses of nitrogen fertilizer that were used in this research did not show significant differences in any of the variables analyzed. The chlorophyll b index was the one that showed the greatest sensitivity to nitrogen doses, presenting the highest coefficient of variation between measurements.

Acknowledgements

To our colleague, Agronomist Mauricio Burgos for his contributions. To the staff of the experimental station of the Faculty of Agronomy in Salto. To the advanced students of the career, Bachelor in Water Resources and Irrigation, Manuel Lira and Pablo Junik.

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