Morphogenic characteristics of black oat and vetch under different densities

Características morfológicas de aveia preta e ervilhaca em diferentes densidades

Características morfogénicas de la avena negra y la veza bajo diferentes densidades

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Pedro Valério Dutra Moraes
PhD in Weed Science
Institution: Universidade Tecnológica Federal do Paraná
Address: Dois Vizinhos – Paraná, Brasil
E-mail: pvdmoraes@gmail.com

João Assis Farias Filho
Graduated in Agronomy
Institution: Universidade Tecnológica Federal do Paraná
Address: Dois Vizinhos – Paraná, Brasil
E-mail: joaodeassis13@hotmail.com

Lucas da Silva Domingues
PhD in Crop Science
Institution: Universidade Tecnológica Federal do Paraná
Address: Dois Vizinhos – Paraná, Brasil
E-mail: lucasdomingues@utfpr.edu.br

Paulo Fernando Adami
PhD in Crop Science
Institution: Universidade Tecnológica Federal do Paraná
Address: Dois Vizinhos – Paraná, Brasil
E-mail: pauloadami@utfpr.edu.br

Leocádio Ceresoli
Master in Agroecosystem
Institution: Universidade Tecnológica Federal do Paraná
Address: Dois Vizinhos – Paraná, Brasil
E-mail: leocadioceresoli20@hotmail.com


**ABSTRACT**

The objective of this study was to assess the morphogenic characteristics *Avena strigosa* and *Vicia sativa* plants cultivated in different sowing densities. The experiment was conducted in vases with farming soil. The experimental design involved randomized units, with four repetitions, consisting of a single vetch plant placed in the centre of each experimental unit and a variable number of oat plants (0, 1, 2, 3, 4, and 5) planted around the borders. The same procedure was also conducted with a single oat plant placed in the centre of the vase and a variable number of vetch plants (0, 1, 2, 3, 4, and 5) planted around the borders. The plants were grown for a total of 35 days. Morphogenic characteristics of the central plant were assessed at the time of transplantation as well as every 7 days. It was observed that the density increase in vetch plants did not significantly influence stem elongation, plant elongation, and leaf senescence rates of oat plants. However, higher densities did reduce the tiller appearance rate in oat plants. Increases in oat density caused significant impacts on the elongation rate and linear growth in the leaf senescence rate and reduced the number of ramifications in vetch plants. Higher density caused reduced leaf appearance and tiller rates while increasing phyllochron values. The results of this study indicate that increases in plant density trigger competition responses in both oat and vetch, which in turn negatively affect many of the assessed morphogenic characteristics for both species.

**Keywords:** competition, leaf elongation rate, leaf senescence rate, phyllochron.

**RESUMO**

O objetivo deste estudo foi avaliar as características morfogênicas de plantas de *Avena strigosa* e *Vicia sativa* cultivadas em diferentes densidades de semeadura. O experimento foi conduzido em vasos com solo agrícola. O delineamento experimental envolveu unidades aleatórias, com quatro repetições, consistindo de uma única planta de ervilhaca colocada no centro de cada unidade experimental e um número variável de plantas de aveia (0, 1, 2, 3, 4 e 5) plantadas ao redor das bordas. O mesmo procedimento também foi realizado com uma única planta de aveia colocada no centro do vaso e um número variável de plantas de ervilhaca (0, 1, 2, 3, 4 e 5) plantadas ao redor das bordas. As plantas foram cultivadas por um total de 35 dias. As características morfogênicas da planta central foram avaliadas no momento do transplante e a cada 7 dias. Observou-se que o aumento da densidade das plantas de ervilhaca não influenciou significativamente o alongamento do caule, o alongamento da planta e as taxas de senescência das folhas das plantas de aveia. No entanto, as densidades mais altas reduziram a taxa de aparecimento de perfilhos nas plantas de aveia. O aumento da densidade da aveia causou impactos significativos na taxa de alongamento e no crescimento linear da taxa de senescência das folhas e reduziu o número de ramificações nas plantas de ervilhaca. A densidade mais alta reduziu a aparência das folhas e as taxas de perfilhamento, ao mesmo tempo em que aumentou os valores de filocrono. Os resultados deste estudo indicam que o aumento da densidade de plantas desencadeia respostas de competição tanto na aveia quanto na ervilhaca, o que, por sua
vez, afeta negativamente muitas das características morfogênicas avaliadas para ambas as espécies.

**Palavras-chave:** competição, taxa de alongamento da folha, taxa de senescência da folha, filocrono.

**RESUMEN**
El objetivo de este estudio fue evaluar las características morfogénicas de plantas de Avena strigosa y Vicia sativa cultivadas en diferentes densidades de siembra. El experimento se realizó en macetas con suelo de cultivo. El diseño experimental incluyó unidades aleatorias, con cuatro repeticiones, consistentes en una sola planta de veza colocada en el centro de cada unidad experimental y un número variable de plantas de avena (0, 1, 2, 3, 4 y 5) plantadas alrededor de los bordes. También se realizó el mismo procedimiento con una sola planta de avena colocada en el centro del jarrón y un número variable de plantas de veza (0, 1, 2, 3, 4 y 5) plantadas alrededor de los bordes. Las plantas se cultivaron durante un total de 35 días. Se evaluaron las características morfogénicas de la planta central en el momento del trasplante, así como cada 7 días. Se observó que el aumento de densidad en las plantas de veza no influyó significativamente en la elongación del tallo, la elongación de la planta y las tasas de senescencia foliar de las plantas de avena. Sin embargo, las densidades más altas sí redujeron la tasa de aparición de macollos en las plantas de avena. Los incrementos en la densidad de avena causaron impactos significativos en la tasa de elongación y crecimiento lineal en la tasa de senescencia foliar y redujeron el número de ramificaciones en las plantas de veza. Una mayor densidad causó una reducción en la aparición de hojas y en la tasa de macollos, al tiempo que aumentó los valores del filocronó. Los resultados de este estudio indican que el aumento de la densidad de plantas desencadena respuestas de competencia tanto en avena como en veza, que a su vez afectan negativamente a muchas de las características morfogénicas evaluadas para ambas especies.

**Palabras clave:** competencia, tasa de elongación foliar, tasa de senescencia foliar, filocronó.

**1 INTRODUCTION**

The use of cover crops during winter in subtropical regions is a technique designed to promote growth in grain production without increasing production costs. The cover crops not only protect the soil from physical harm and erosion, but also promote nutrient cycling and, when leguminous plants are used, they aid atmospheric nitrogen fixation (Da Silva et al., 2007).

The use of oat combined with vetch is considered a suitable option for a winter cover crop as it combines the positive characteristics of both species, such as a high capacity for biomass accumulation, resistance to diseases and pests, and the capacity to fix atmospheric nitrogen, thus improving the nitrogen balance in the soil and resulting in numerous benefits for the succession cultivars (Heinrichs et al., 2001).
In addition to their use as cover crops, they serve as pasture forage plants. Oat is one of the most commonly used species in the South of Brazil due to its hardiness, high capacity for tillering, and biomass production (Carvalho et al., 2007), while vetch is able to facilitate the availability of a higher amount of nitrogen to oat plants, as well as promote improvements in animal diet and performance owing to its high protein content (Barcellos et al., 2008).

However, the consortium of grasses and legumes presents difficulties for sowing and managing pastures and the use of these two species together for soil coverage may not fully express the potential of each individual species alone. For these reasons, it is necessary to analyze the morphogenic characteristics of these two species in consortium in order to understand the best way of using them, as well as to subsequently inform choices for pasture handling to promote sustainability in livestock-plantation integration systems (Quadros et al., 2005).

Notably, morphogenic characteristics can be influenced by factors such as luminosity, temperature, water, and nutrient availability (Lemaire & Chapman, 1996). As plants grown in consortium have been known to show competitive effects between plants, resulting in varying responses in both plants, the aim of this study was to assess the morphogenic characteristics of black oat and common vetch when grown in consortium with different sowing densities.

2 MATERIALS AND METHODS

2.1 EXPERIMENT SITE

The study was in a vegetation house from the Experimental Station at Universidade Tecnológica Federal do Paraná – Campus Dois Vizinhos, located in the Southern region of the State of Paraná, at an altitude of 520 meters, latitude of 25º44” S and longitude of 54º04” W.

2.2 EXPERIMENT CONDUCTION

Experimental units correspond to vases with an area of 0.018 m² and the capacity of 2 L, containing dystroferric red Nitisol (Ultisol) taken from the surface at a depth of 0 to 20 cm of a plantation area where soy was previously cultivated. The treatments comprised black oat (Avena strigosa) plants cv. IAPAR 61 in consortium with common vetch (Vicia sativa) plants cv.
Ametista under different sowing density levels. Completely randomized design with 4 repetitions was used.

Firstly, both species were sown in trays containing commercial substrate, having the sowing performed in order to have both species sprouting on the same date so to avoid differences in the plants’ state when submitted to consortium.

Seven days after sprouting, the transplanting of both species was performed. During transplantation, a vetch plant was put in the middle of the vase and a variable number of oat plants (0, 1, 2, 3, 4, 5) was planted on the borders. The same procedure was done when planting oat in the middle of each experimental unit and a variable number of vetch plants (0, 1, 2, 3, 4, 5) on the borders. Each bordering plant was placed five cm from the central plant, while bordering plants were placed equidistant from each other, with the distance varying according to the treatment, following the methodology of additive experiments used for assessing the competition between plants (Radosevich et al. 1997).

Irrigation was performed daily during the afternoons, having the same amount of water applied to all vases. Weed control was performed manually whenever needed and fertilization was not performed in order to potentialize the effect of competition between plants, which grew in consortium during 35 days after transplanting.

2.3 FIELD MEASUREMENTS

During the consortium period, six measurements were performed to assess the morphogenic characteristics of central plants, one having been performed at transplanting date and other five at each seven days.

For oat plants, the following measurements were performed:
  - Plant height: distance between the beginning of stem to the top of the last mature leaf
  - Stem length: distance between the beginning of stem and the ligule of the last mature leaf
  - Number of mature leaves (NML): number of leaves with exposed ligule
  - Number of expanding leaves (NEL): number of leaves with not yet exposed ligule
  - Number of senescent leaves (NSL): number of leaves with senescence signs
  - Number of tillers per plant (NTP): number of basal tillers of the main tiller
For vetch plants, the following measurements were performed:
- Plant height: distance between the beginning of stem to the top of the last expanded leaf
- Number of mature leaflets (NML): number of completely open leaflets
- Number of expanding leaflets (NEL): number of partly open leaflets
- Number of senescent leaflets (NSL): number of leaflets with senescence signs
- Number of ramifications per plant (NRP): number of primary and secondary ramifications.

2.4 ESTIMATED VARIABLES

Based on the measures taken from oat plants, the following variables were estimated:
- Plant elongation rate (PELR) = (final height – initial height) / no. days
- Stem elongation rate (SELR) = (final – initial length) / no. days
- Leaf appearance rate (LApR) = (ΣNLE / no. measurements) / no. days
- Phyllochron = no. days / (ΣNLE / no. measurements)
- Leaf senescence rate (LSR) = (ΣNLS / no. measurements) / no. days
- Number of leaves per plant (NLP) = Σ(NLE+NLM) / no. measurements
- Tiller appearance rate (TApR) = ΣNTP / no. days

Based on the measures taken from vetch plants, the following variables were estimated:
- Plant elongation rate (PELR) = (final height – initial height) / no. days
- Leaflet appearance rate (LApR) = (ΣNLE / no. measurements) / no. days
- Phyllochron = no. days / (ΣNLE / no. measurements)
- Leaflet senescence rate (LSR) = (ΣNLS / no. measurements) / no. days
- Number of leaflets per plant (NLP) = Σ(NLE+NLM) / no. measurements

2.5 STATISTICAL ANALYSIS

The data were submitted to variance analysis by the F test at 5% of probability and, when significant, the regression analysis through orthogonal polynomials method was performed using the statistical program ASSISTAT (Silva & Azevedo 2009).
3 RESULTS AND DISCUSSION

3.1 MORPHOGENIC CHARACTERISTICS OF BLACK OAT UNDER VARYING VETCH DENSITIES

Stem elongation rates of oat plants did not display significant response in relation to sowing density (P > 0.05). It was expected that as density increased and available resources decreased, plant size would decrease in response. However, as indicated by Zanine and Santos (2004), grass plants exhibit an observable increase in tillers under low levels of competition in order to increase the competitiveness of the species.

Thus, despite the reduction in available resources, oat plants grown in higher densities may expend more energy for stem elongation, and thereby reach a similar size to plants in low densities experiencing lower levels of competition.

Leaf appearance rates decreased linearly with the increase in the number of plants grown in consortium (Figure 1a) and consequently resulted in a linear increase in phyllochron values (Figure 1b).

Figure 1. Leaf appearance rate (a) and phyllochron (b) in oat plants under different vetch plant densities.

Plants grown in isolation were observed to have higher rates of leaf appearance and lower phyllochron rates as there was no competition among plants in this treatment. However, as the number of plants in consortium increased, the competition for available resources increased, which negatively impacted the appearance of new leaves. According to Gomide & Gomide (2000), leaf appearance rates are significantly impacted by changes in the environment.
Additionally, water availability may play a role in reducing new leaf emission as does the availability of nutrients in soil, as observed by Martuscello et al. (2011), when working with nitrogen (N) doses on *Brachiaria decumbens*, and by Quadros et al. (2005), when evaluating the phosphorus (P) and potassium (K) fertilization levels on *Paspalum urvillei*. The increase in competition may have reduced the availability of water and nutrients for the assessed plants resulting in a reduction in leaf appearance rate and an increase in the time period before the production of new leaves.

The number of tillers per plant, and tiller appearance rates were also impacted by the number of vetch plants in consortium. There was an observed linear reduction in these variables as density increased (Figure 2a and 2b). As the density of vetch plants increased, the incidence of sunlight on the base of the central tiller may have decreased causing a decrease in tiller production, as grass species are known to reduce tillering in order to be more competitive in the search for light (Zanine & Santos, 2004).

Leaf senescence rates were not significantly influenced by density (P > 0.05). Lower rates of leaf senescence may be connected to a lower rate of overall growth as observed by Szymczak et al. (2016) in Guinea grass tillers subjected to different shade levels. Despite the differences obtained with respect to leaf appearance rate, the number of live leaves was not influenced by plant density (P > 0.05). This could be attributed to no differences in the leaf senescence rates.
3.2 MORPHOGENIC CHARACTERISTICS OF VETCH UNDER VARYING BLACK OAT DENSITIES

A quadratic response to varying black oat densities in vetch stem elongation rates was observed (Figure 3a).

Figure 3. Plant elongation rate (a) and number of ramifications per plant (B) of vetch plants under different oat plant densities.

Source: João de Assis Farias

Higher elongation rates corresponded to vetch plants grown in isolation as the absence of competition enable these plants to develop without any negative interference. As the number of oat plants increased, a reduction in vetch stem elongation rates was observed until the density reached four oat plants, whereupon there was an observable increase in stem elongation rates. It is possible that in the consortiums with lower densities of oat plants (1, 2, and 3), competition for soil had higher significance for vetch plant sizes, while in the consortiums with higher densities of oat plants (4, 5, and 6), the responses in elongation rates appeared to be mainly related to competition in the shoot system.

Higher densities of oat plants may have resulted in a denser canopy and subsequently reduced light availability for vetch plants prompting them to elongate their shoot systems in search for increased light levels (Taiz & Zeiger 2004).

The number of ramifications decreased linearly as density increased (Figure 3b). Vetch grown in isolation demonstrated larger lengths and a higher number of ramifications in the absence of any competition. The lower number of ramifications in plants in consortium with four and five oat plants may also be associated with competition for light, given that one strategy...
plants use when faced with a light shortage is to increase photoassimilate translocation in the main stem and reduce the development of lateral buds (Sangoi et al. 2002).

In oat plant densities above 3, a tendency for plant elongation was observed (Figure 3a). These responses were also observed in *Arachis pintoi*, a species that demonstrated high ramification rates in conditions of high light availability while prioritizing leaf production emission in the upper third of the plant and elongation of the stem under low light conditions (Sá, 2013).

Leaflet appearance rates decreased linearly, while the phyllochron values increased linearly (Figures 4a and 4b). As previously observed for oat plants, these variables are highly sensitive to environmental changes (Gomide & Gomide 2000) and may be impacted by water availability and soil nutrients levels (Martuscello et al. 2011; Quadros et al. 2005).

Figure 4. Leaflet appearance rate (a) and phyllochron (b) of vetch plants under different oat plant densities.

Leaf senescence rate increased with the increase of oat plant density in consortium (Figure 5a). “These results may be connected to water availability in soil because, as plant competition increases, resource availability decreases leading to an increase in the synthesis of ethylene and abscisic acid. This in turn results in increased leaf senescence and abscission rates as the plant attempts to keep itself alive by conserving energy and lowering transpiration rates (Taiz & Zeiger, 2004).
Under conditions of ample water and light availability, and suitable temperatures, *Arachis pintoi* has lower leaf senescence rates (Sá, 2013). This has also been observed to be the case with vetch as, when planted in isolation, there was no observable leaf senescence.

The number of live leaves per plant matched a quadratic regression, with the tendency to value diminution as the number of plants in consortium increased (Figure 5b). These results were obtained by joining the responses obtained from the analysis of the other variables. It was observed that isolated plants presented higher numbers of ramifications, higher rates of leaflet appearance, and lower rates of leaf senescence, resulting in higher numbers of live leaves as opposed to plants grown in consortium with four or five oat plants, which presented on average 28 fewer leaflets than plants in isolation.

**4 CONCLUSIONS**

The increase of plant density caused lower leaf appearance rates and increased the number of days for the appearance of two consecutive oat and vetch leaves. However, these results affected only the total number of vetch plants.

Larger vetch populational densities caused lower oat plant tillering; however, it did not affect the stem and plant elongation rates of this species. On the other hand, the increase in the number of oat plants in consortium resulted on differences in the size of vetch plants and reduced the number of ramifications per plant.
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