# Effect of animal manure-based substrates on the emergence and vegetative growth of fodder oats (*Avena sativa* L.)

Efecto de sustratos a base de estiércol de animales sobre la emergencia y el crecimiento vegetativo de avena forrajera (*Avena sativa* L.)

Efeito dos substratos à base de esterco animal no aparecimento e crescimento vegetativo da aveia forrageira (*Avena sativa* L.)

Angel Canales Gutiérrez*
Guadalupe Sucari Turpo

Universidad Nacional del Altiplano de Puno. Facultad de Ciencias Biológicas. Programa de Ecología. Puno. Perú.

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## Abstract

Oats (*Avena sativa* L.) are an annual forage grass of great current and potential importance in agricultural development. The objective was to determine the effect of animal manure-based substrates on the emergence and vegetative growth (stem height and leaf length) of forage oats (*Avena sativa* L.) in relation to organic amendments (chicken-cuy, cattle-sheep, llama-alpaca) over time. Growth variables were measured every ten days up to 60 days. A completely randomised experimental design was used; each treatment consisted of five replicates of ten seeds each. Analysis of variance (ANDEVA), Tukey's multiple comparison and regression and correlation analysis were performed. Both stem height and leaf length were higher when the seeds were established on a substrate based on a mixture of cattle and sheep manure and were lower with the llama-alpaca manure mixture. In general, growth expressed in stem height and leaf length increased over time. The application of organic matter of animal origin improves the quality of agricultural soils, which is reflected in plant growth and development.

*Corresponding author: acanales@unap.edu.pe

## Resumen

La avena (*Avena sativa* L.), es una gramínea forrajera anual de gran importancia actual y potencial en el desarrollo de la agricultura. El objetivo fue determinar el efecto de sustratos a base de estiércol de animales sobre la emergencia y el crecimiento vegetativo (altura del tallo y longitud de hojas) de la avena forrajera (*Avena sativa* L.) en relación con las enmiendas orgánicas (gallina-cuy, vacuno-ovino, llama-alpaca) en el tiempo, las variables de crecimiento se midieron cada diez días hasta los 60 días. Se utilizó un diseño experimental completamente aleatorizado; cada tratamiento constó de cinco repeticiones de diez semillas cada uno. Se realizaron análisis de varianza (ANDEVA), la comparación múltiple de Tukey y el análisis de regresión y correlación. Tanto la altura de tallo como la longitud de la hoja, fueron mayores cuando las semillas se establecieron en un sustrato a base de la mezcla estiércol de vacuno-ovino y fueron menores con la mezcla de estiércol llama-alpaca. En lineas generales, el crecimiento expresado en la altura del tallo y la longitud de la hoja se incrementó en el tiempo. La aplicación de materia orgánica de origen animal mejora la calidad de los suelos agrícolas, lo cual se refleja en el crecimiento y desarrollo de las plantas.


**Palabras clave**: cereal, crecimiento, materia orgánica.


## Resumo

A aveia (*Avena sativa* L.) é uma erva forrageira anual de grande importância atual e potencial no desenvolvimento agrícola. O objetivo era determinar o efeito dos substratos à base de esterco animal no aparecimento e crescimento vegetativo (altura do caule e comprimento das folhas) da aveia forrageira (*Avena sativa* L.) em relação às emendas orgânicas (galinha-cuy, pecuária- ovelha, llama-alpaca) ao longo do tempo. As variáveis de crescimento foram medidas a cada dez dias até 60 dias. Foi utilizado um desenho experimental completamente aleatório; cada tratamento consistia de cinco réplicas de dez sementes cada. Análise de variância (ANDEVA), a comparação múltipla de Tukey e a análise de regressão e correlação foram realizadas. Tanto a altura do caule quanto o comprimento das folhas eram maiores quando as sementes eram estabelecidas em um substrato baseado em uma mistura de esterco bovino e ovino e eram mais baixas com a mistura de esterco de llama-alpaca. Em geral, o crescimento expresso na altura do caule e no comprimento da folha aumentou com o tempo. A aplicação de matéria orgânica de origem animal melhora a qualidade dos solos agrícolas, o que se reflete no crescimento e desenvolvimento das plantas.


**Palavras-chave:** cereais, crescimento, matéria orgânica.

## Introduction

Oats (*Avena sativa* L.), is a monocotyledonous, annual herbaceous plant belonging to the Poaceae family (Suasaca *et al*., 2020), has a large number of varieties and are distributed in a wide diversity of altitudinal floors ranging from 2,500 to 4,000 meters above sea level. (Espinoza *et al*., 2018). It is undoubtedly a crop of wide climatic adaptation (Servin *et al*., 2018) and important as forage (Espinoza *et al*., 2018), as it has good nutritional and energy quality (Flores *et al*., 2016); it can be used from its growth stage (Espitia *et al*., 2012), in silage or hay (Condori *et al*., 2019) and for livestock feed (Rodríguez *et al*., 2020).

Among the forage species, oats, is widely cultivated in Peru (Mamani and Cotacallapa, 2018), despite the constant challenges it confronts (droughts and frosts) (Benique, 2019); in turn these occur with increasing intensity (Hijar *et al*., 2016) and therefore planting is done in the rainy season (December, January and February), where rainfall is recommended, being the harvest in March and April (Huallpa *et al*., 2016).

The use of animal manure in agriculture is very important (Ávalos de la Cruz *et al*., 2018), since it provides various nutrients that crops need for their development (Huerta *et al*., 2019) and increased production (Muñoz *et al*., 2016), and its use is of great social and environmental importance (Huerta *et al*., 2019). In the high Andes, there is evidence of loss of productive areas and an increase in degraded soils from 35 to 120 ha (Loza and Taype, 2021). Soil degradation has negative effects on plant yields; one of the factors is salinization, which influences the decrease in the biological fertility of the soil. The application of organic amendments increases enzymatic activity and soil respiration, reduces soil pH and electrical conductivity. The addition of organic fertilizer influences a higher rate of nitrogen mineralization and higher urease activity (Mogollón *et al*., 2011). Therefore, the incorporation of organic materials of animal or plant origin to soils has been shown to improve their physical, chemical and biological conditions, having effects on crop yield (Arrieche and Ruiz, 2014).

The objective was to determine the effect of animal manure-based substrates on the emergence and vegetative growth of forage oats (*Avena sativa* L.) in relation to organic amendments over time.

## Materials and Methods

The study was conducted in the District of Asillo, Peru at 3,913 m.a.s.l. (coordinates 14°47′34″S; 70°21′22″W), with mean annual temperature of 16 °C and monthly precipitation of 153 mm (Huallpa *et al*., 2016).

Two hundred seeds of *Avena sativa* L., selected on the basis of size and color, were sown in perforated trays, with ten seeds per replicate and five replicates per treatment. Irrigation was carried out every 2 days, with 250 mL of water for each treatment (table 1).

**Table 1. Proportion of animal manure for each treatment.**

| Treatment | Substrate | Ratio |
|---|---|---|
| Control (T0) | Tierra agrícola | |
| T1 | Agricultural land + chicken manure + guinea pig manure | 2:0.25:0.25. |
| T2 | Agricultural land + cattle manure + sheep manure | 2:0.25:0.25. |
| T3 | Agricultural soil + llama manure + alpaca manure | 2:0.25:0.25. |

Manures from chicken (*Gallus gallus domesticus*), bovine (*Bos taurus*), llama (*Lama glama*), sheep (*Ovis orientalis*), alpaca (*Vicugna pacos*) and cuy (*Cavia porcellus*), which were collected from the field (corral), then crushed and applied to the trays for each treatment, were evaluated.

**The variables evaluated were:**

Emergency percentage (E%): the number of emerged seeds was determined by the following formula:

$$\% E = \frac{Number\ of\ seedlingd\ emerged\ in\ the\ last\ count}{Number\ of\ seeds\ sown}$$

Stem height: measurements were made on three individuals at random for each tray, using a tape measure.

Leaf length: measurements were made on three individuals at random for each tray, using a tape measure.

Leaf and stem growth was recorded during 60 days (December 2020 - February 2021). Observations were made from day 25, every five days from 09:00 to 11:00 h, randomly selecting three individuals per tray.

The experimental design used was a completely randomized design. An analysis of variance (ANDEVA) was performed, and Tukey's test of measures was used to determine the differences between treatments. Likewise, a regression analysis was performed to determine the relationship of the growth variables with respect to the evaluation time, and a correlation analysis was performed to determine the association between the variables studied. The statistical program INFOSTAT (2020), licensed for use, was used for all analyses.

## Results and discussion

The percentage of emergence at 10 days was 76, 0, 14 and 50 %, for T0, T1, T2 and T3, respectively; while at 15 days the percentage of emergence was 100 % for T0, T2 and T3; T1 registered 26 % and at 20 days it presented 100 % of emergence, being the latest treatment. The time of seed emergence is reflected by the environmental conditions of the soil (Vargas, 1991) and the concentration of phytic acid in the seeds, due to the effect of fertilizers, which generates their vigor (Rivera *et al*., 2009).

Pino *et al*. (2008) indicated that in soils added with fresh poultry manure, mineralized N correlates more closely with uric acid content, which could be the cause of the lower percentage of emergence in T1. In contrast, T0 caused emergence in less time, and T2 and T3 treatments showed similar behavior.

As for the variables measuring vegetative growth, highly significant differences between treatments were recorded for stem height and leaf length ($p < 0.01$) (table 2).

**Table 2. Analysis of Variance (ANDEVA) for oat stem and leaf growth in different animal manure-based substrate mixtures.**

| | | | | | |
|---|---|---|---|---|---|
| | | Stem | | | |
| S.V. | **SS** | **DF** | **MS** | **F** | ***p*-valor** |
| Model | 704.18 | 3 | 234.73 | 8.09 | <0.0001 |
| Treatment | 704.18 | 3 | 234.73 | 8.09 | <0.0001 |
| Error | 12,585.36 | 434 | 29 | | |
| Total | 13,289.54 | 437 | | | |
| | | Leaf | | | |
| Model | 1,420.21 | 3 | 473.4 | 11.6 | <0.0001 |
| Treatment | 1,420.21 | 3 | 473.4 | 11.6 | <0.0001 |
| Error | 17,718.5 | 434 | 40.83 | | |
| Total | 19,138.7 | 437 | | | |

Stem height was greater in T2 and T0 with averages of 11.75 and 10.03 cm, respectively; while for T1 and T3 it was lower, with averages of 9.67 and 8.35 cm, respectively (table 3).

**Table 3. Stem height and leaf length in Avena sativa in mixtures of different organic substrates.**

| Treatment | Stem height (cm) | Leaf length (cm) |
|---|---|---|
| T0: control | 10.03 ab | 18.55 b |
| T1: Chicken-cuy | 9.67 a | 14.71 a |
| T2: Bovine-sheep | 11.75 b | 18.72 b |
| T3: Llama-alpaca | 8.35 a | 14.71 a |

Means with a common letter are not significantly different ($p > 0.05$).

It has been established that plant development is influenced by the composition and type of soil (Castro *et al*., 2015).

The development of stems and leaves, is related to the use of various types of manure from domestic animals (Avalos de la Cruz *et al*., 2018), which possess the necessary macroelements such as $N\text{-}P_2O_5\text{-}K_2O$ that are applied during sowing and in tillering (INIA, 2006), being an important aspect for agriculture (Avalos de la Cruz *et al*., 2018).

The effect of organic manure mixed with inorganic, influences the increase of nutrients for forage oats (Bar-Tal *et al*., 2004; Torres *et al*., 2016), this increase of nutrients influences the growth of all parts of the plant. The use of compost, as organic fertilizer, also influenced the increase of organic matter in the soil for the production of forage oats (Montaño *et al*., 2017), in the research conducted only animal manure was applied. There was a positive trend of increase in stem height and leaf length in all treatments in relation to time (10, 20, 30, 40, 50 and 60 days). Figure 1 shows the increase in stem height.

The regression coefficient for stem height at T0 was: $r^2 = 0.88$; $Y = - 6.87 + 0.40\ X$, while for leaf length (cm) it was: $r^2 = 0.63$; $Y = 1.79 + 0.39\ X$. For T1 in stem height it was: $r^2 = 0.90$; $Y = - 15.21 + 0.60\ X$.

The regression coefficient for T2 in stem height was: $r^2 = 0.87$; $Y = - 7.55 + 0.45\ X$, while for leaf length it was: $r^2 = 0.61$; $Y = 1.34 + 0.41\ X$. For T3 in stem height it was: $r^2 = 0.78$; $Y = - 3.23 + 0.27\ X$.

As can be evidenced by the results of the regression analysis in all treatments, there was a significant response in terms of stem height and leaf length with respect to time.

Organic manures are important sources of organic carbon (Ren *et al*., 2014) together with the application of fertilizers substantially improve plant growth and yields (Mahmood *et al*., 2017; Torres *et al*., 2016), due to the increase of organic matter in the soil (Montaño *et al*., 2017), which plants require for their development (Huerta *et al*., 2019).

The values of Pearson's correlation coefficients (r), between stem height and leaf length, showed a positive trend, which were determined by the effect of the different animal fertilizers (T0 = 0.71, T1 = 0.91, T2 = 0.78 and T3 = 0.63) (figure 2).

As can be seen in figure 2, there is a high correlation between stem height and leaf length which registered a high coefficient ($r = 0.91$) for T1, while for T3 ($r = 0.63$) it was lower. With the application of organic matter (animal manure) in soils, biological and physicochemical properties are improved (Cairo and Alvarez, 2017), allowing higher yield and plant productivity (Torres *et al*., 2016). Therefore, it has been determined that there is a leaf/stem ratio of 38/62 until maturity in oats (INIA, 2008), and as it advances in its development the leaf area decreases (Pereira and Grabowski, 2015).

In the Peruvian altiplano, soils show evidence of increasing loss of productive areas (Muñoz *et al*., 2016). This soil degradation process has negative effects on crop yield. Therefore, by applying soil amendments, enzymatic activity increases, pH improves and there is a greater mineralization of nitrogen (Muñoz *et al*., 2016).

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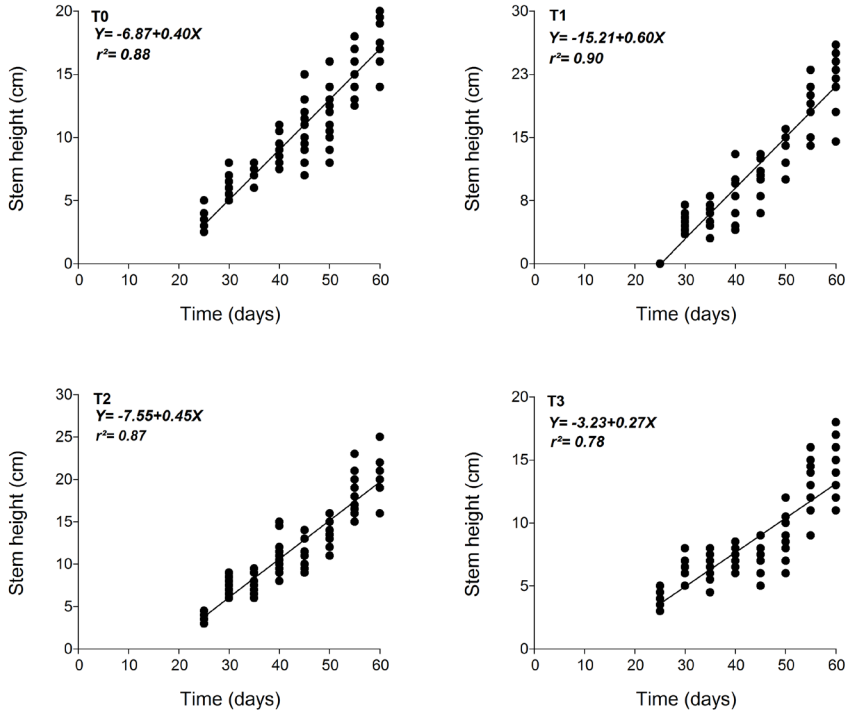


**Figure 1. Stem growth (cm) in different manure-based substrate mixtures (T0= control, T1=chicken-cuy, T2=bovine-sheep and T3=plain-alpaca) over time.**

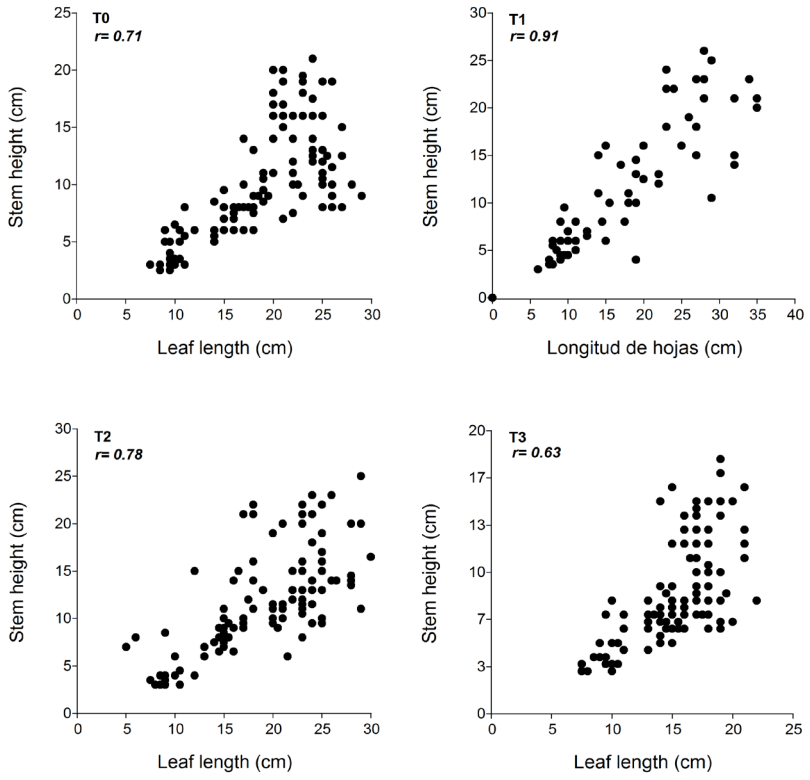


**Figure2. Correlation between stem height (cm) and leaf length (cm) of *Avena sativa*, established in different manure-based substrate mixtures (T0= control, T1= chicken-cuy, T2= bovine-sheep and T3= llama-alpaca).**

## Conclusions

The bovine-sheep manure, llama-alpaca and the control reached a percentage of oat seed emergence of 100% in the shortest time (15 days), while with the chicken-cuy mixture it was 20 days. The shorter emergence time is important for obtaining and availability of oat plants, reducing the time of activities associated with propagation, optimizing the family economy.

Stem height and leaf length were greater when the seeds were established in a substrate based on a mixture of cattle and sheep manure, with the consequent increase in fresh and dry matter of the plants, and were lower with the llama-alpaca manure mixture.

In general terms, growth expressed in stem height and leaf length increased over time due to the effect of the different organic substrates used for oat germination, being an alternative to the use of inorganic fertilizers that favor soil degradation.

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