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Yield estimation of forage oat (*Avena sativa* L.) Chihuahua variety: ruler and plate methods

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ABSTRACT

Objetive: To analyze forage estimations with the direct method and the plant height.

Design/methodology/approach: The treatments were the plants age, assessed in a random block design. Simple linear regressions were carried out and adjusted using the SPSS statistical software.

Results: The highest and lowest yields occurred at 105 and 30 days after sowing (DAS), with 5,412 and 783 kg DM ha^{-1}, respectively. Height with the rule had a significant effect on forage production, with an R^2 of 0.83. For each increase per cm the plants increased 56,134 kg DM ha^{-1} within the studied range. The height with the plate had an R^2 of 0.97, so that 65.032 kg DM ha^{-1} are produced for each cm in height.

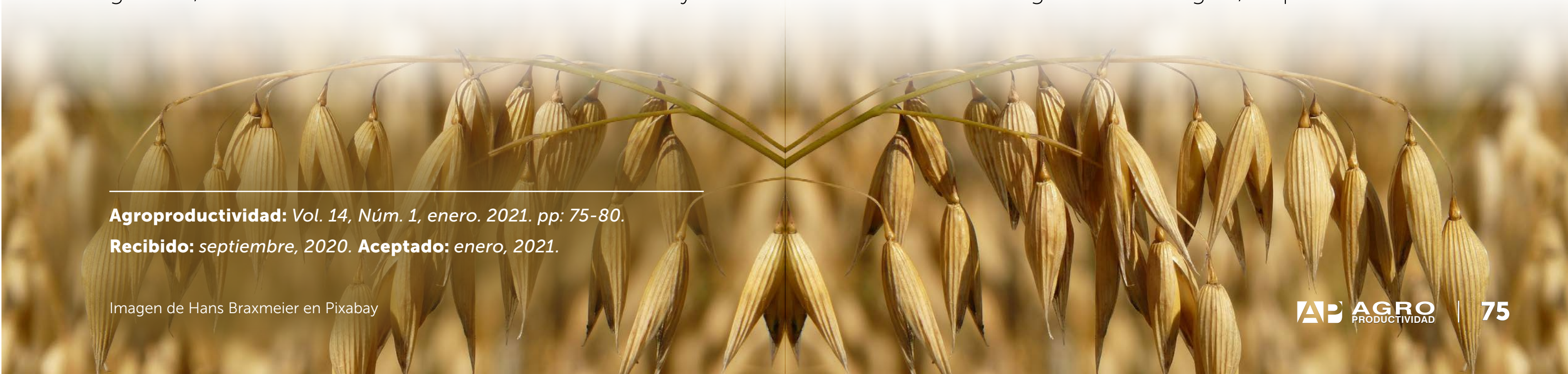
Study limitations/Implications: None

Findings/conclusions: The forage accumulation in *Avena sativa* L., var. Chihuahua varied depending on the age of the plant. The heights calculated with the plate method, had greater reliability for the forage yield estimate, compared to the graduated rule method.

Keywords: Estimation methods, plant height, forage yield.

INTRODUCTION

Avena sativa L. is a cereal adapted to different climatic conditions (Sosa *et al*., 2020), which makes it an available forage source during the dry seasons (Ávila *et al*., 2006). Recently, its sown area has increased, so that the agricultural land usage has changed (Zartash *et al*., 2018). However, forage species such as alfalfa (*Medicago sativa* L.) are widely used in agricultural production systems; never the less, they decrease their dry matter production during winter (Moreno *et al*., 2002). For this reason cereals such as oats, barley and triticale are viable alternatives (Feyissa *et al*., 2007). Therefore, the description of its growth, biomass accumulation and the statistically validated evaluation of management strategies, require tools such



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as growth analysis models (Di Benedetto and Tognetti, 2016), to also determine their animal load, these requires frequent plant growth and forage production measurements (Castro *et al*., 2011). Forage availability can be directly or indirectly estimated, the most accurate way, by the direct cut method, since it provides an objective indicator of the forage yield, as long as the number of samples is adequate (López *et al*. , 2011). This method is destructive and involves time investment, work and equipment (Mannetje, 2000). Therefore, fast, accurate and unbiased measurement variables are required, which correlate with forage availability (Castilo *et al*., 2009). Some of the recently developed involve the forage availability, pasture height and density (Hepp *et al*., 2017a), given that they are associated with growth and productivity (Hakl *et al*., 2012). For this, different instruments are used, among which: the compressed height meter or measuring plate, graduated ruler, capacitance rod, stand out. These require corroboration through calibration equations and prediction models (Hepp *et al*., 2017b). Therefore, the objective of this study was to analyze the estimate of available forage, of oats (*Avena sativa* L.), var. Chihuahua, through the direct and plant height methods, determined via the graduated ruler and measuring plate methods.

MATERIALS AND METHODS

Experimental site

The study was conducted from august, 2018 to january, 2019, at the Colegio de Postgraduados, Campus Montecillo, Texcoco, Estado de México (19° 29' N, 98° 53' W and 2240 m). The climate is temperate subhumid, the driest of this group, with an accumulated annual rainfall of 636.5 mm, with rains in summer (June to October) and an average annual temperature of 15.2 °C (García, 2004). The soil is sandy loam, slightly alkaline, with a pH of 7.8 and 2.4 g (100 g)$^{-1}$ of organic matter (Wilson *et al*., 2018). The weather data was obtained from an agrometeorological station located 1 km from the experimental area (Figure 1).

Pasture management

An oat meadow (*Avena sativa* L.), var. Chihuahua. Fifteen 64 m^2 (8×8 m) plots were delimited on August 24, 2018. Seeds were broadcast sowed, at a sowing density of 115 kg SPV ha^{-1}, with 95% purity and 94% germination. No fertilization was applied, but gravity irrigation was provided every 15 days at field capacity, during dry season. Evaluations took place every 15 days, 30 to 135 days after sowing (DAS).

Experimental design and treatments

The treatments were the plants age and were distributed in a random block design. The experimental units were 64 m^2 plots, which represented the plant age (DAS).

Experimental evaluations

The average height of each experimental plot was determined by two estimation methods: 1) Graduated ruler method: a one-meter length graduated wooden ruler, a 1 cm precision was used, placed vertically from the base of the plant up to the last upper component,

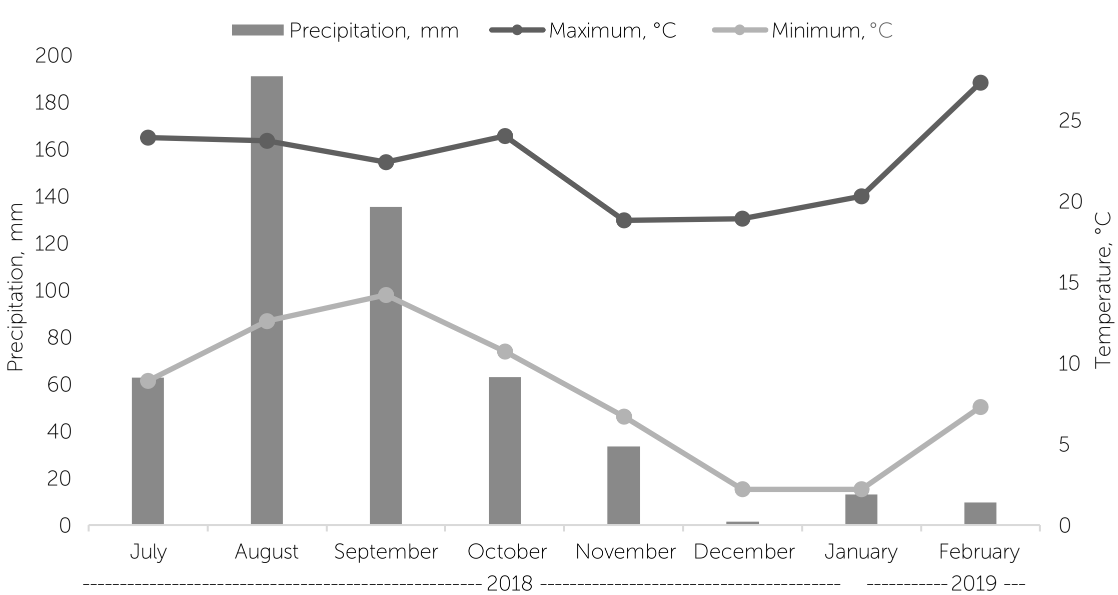

Figure 1. Maximum and minimum average temperatures (lines, vertical secondary axis) and accumulated precipitation (bars, vertical primary axis) from July 2018 to February 2019.

without disturbing the plant (Hodgson *et al.*, 1999). 2) Plate method (Jenquip®): a 50×50 cm aluminum plate was used, slide on its axis, compressing the mass of forage with the plate's weight (Hepp *et al.*, 2017a). Ten random readings (30 readings per plant age) were taken for each method. With the direct method, the forage weight (kg DM ha^{-1}) was determined, using two quadrants of 0.25 m^2 (50×50 cm), in which the forage was harvested from ground level and dried for 72 ha 55 °C in a forced air stove (Mod. Felisa FE-243A) until constant weight (López *et al.*, 2011).

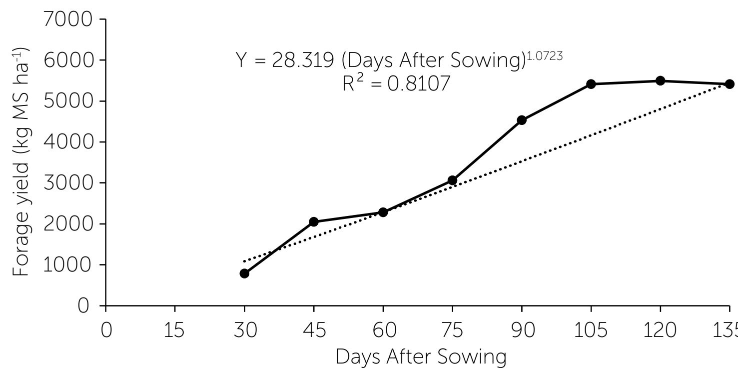

Figure 2. Forage yield curve (Y) in oat (*Avena sativa* L.) var. Chihuahua, harvested at different plant ages.

Statistical analysis

Simple linear regressions were performed; DMY=ALT (b); where DMY=Dry Matter Yield, ALT=Plant height, and b=is the regression coefficient in kg DM ha^{-1} per cm of plant height, with DMY and ALT already defined (Santillan *et al.*, 1979). The regressions were adjusted with the Statistical Package for Social Sciences software (SPSS, 2011), the significance of the correlation coefficients was calculated ($p<0.05$) and an analysis of variance and a means comparison (Tukey; $p<0.05$) were assessed.

RESULTS AND DISCUSSION

Relationship between yield and plant age

The forage yield of *Avena sativa* L., var. Chihuahua, was significantly different ($p<0.05$) at different ages of the plants (Figure 2). The best fit regression model was that of the potential, with $R^2=0.81$; therefore, the DMY was positively correlated with the age of the plant, given that 81% of the total variability of the DM yield data was explained in by the plants age. The differences ($p<0.05$) were observed at 105 DAS with 5412 kg DM ha^{-1}, respect to the first age (30 DAS, with 783 kg DM ha^{-1}), later the curve became asymptotic. This trend is observed when the rate of senescence and decomposition exceeds the rate of leaf and stem production (Hernández *et al.*, 1999). In temperate grasses, DM accumulation is maintained until week seven or eight of regrowth and decreases once the meadow reaches an optimal leaf area index, due to self-shading at the base of the plants (Chapman and Lemaire, 1993). Wilson *et al.* (2018), in var. Turqueza reported at 112 DDS 6.702 kg DM ha^{-1}, and in var. Saia, at 141 DAS 12,188 kg DM ha^{-1}, in a milky-mass state. For their part, Zartash *et al.* (2018) report 5,000 kg DM ha^{-1}, at 160 DAS and Hernández *et al.* (2018) in var. Chihuahua, 6,074 kg DM ha^{-1}, at 164 DAS. Therefore, the results of this study have no high differences with that reported in previous research, although these developed in different climate and soil conditions (Wilson *et al.*, 2017).

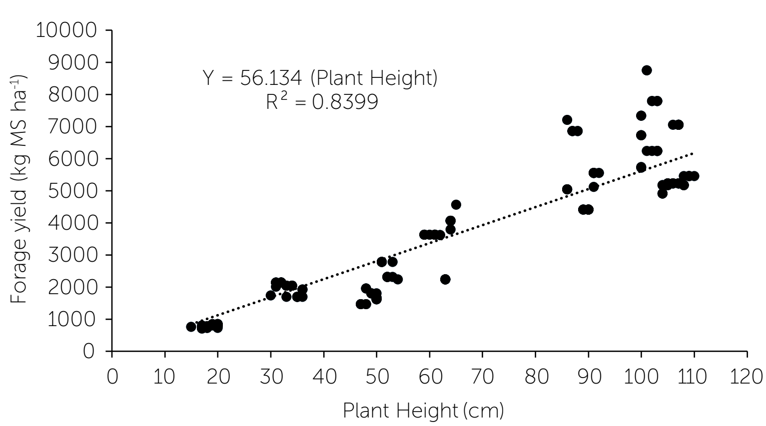

Figure 3. Linear regression between the non-compressed heights (X) obtained with the ruler method and yield (Y) in oat (*Avena sativa* L.) var. Chihuahua, harvested at different plant ages. The slope of the line was statistically different from zero ($P<0.05$) but not the intercept ($P>0.05$).

Linear equations between yield and ruler height

The height with the graduated rule had a significant effect ($p<0.05$) on the DM production of oats (*Avena sativa* L.), var. Chihuahua. The regression equation showed an acceptable fit range (Figure 3), since the variation in DM performance was determined by at least 83% by the variation of the height measured with rule ($R^2=0.83$), that is, for each cm of increase in height, the forage yield increased 56,134 kg DM ha^{-1}. The above suggests that the estimated height with a ruler is a useful and practical tool to estimate DM yield in *Avena sativa*, var. Chihuahua. However, in cutting herbaceous plants in the United States, the rule method was reported as the least reliable, given its low coefficient of determination ($R^2=0.37$) and respect to the plate ($R^2=0.59$) (Gangulli *et al.*, 2000). Likewise, in Gramineae -

fabaceae meadows in Pennsylvania, West Virginia and Maryland, USA, correlation coefficients of R^2=0.16 were reported, respect to a capacitance meter (R^2=0.31), reporting error rates of 26 and 33 % (Sanderson *et al.*, 2001). Therefore, to obtain reliable yield estimates from the height of the plants with a graduated rule, regression equations must be generated for each management condition and forage species (Castillo *et al.*, 2009).

Linear equation between yield and height with plate

The relationship between the height with the plate and the forage yield, of oats (*Avena sativa* L.) had a significant effect (p<0.05). The equation showed an adjustment to a simple linear model (Figure 4) with an R^2 value of 0.97, which indicates that 97% of the variation in the DM yield is explained by the height via the plate, obtaining 65,032 kg DM ha^{-1} for each cm of plant height. This technique exceeds the reliability of the rule method, since its correlation coefficient is higher (0.97 *vs* 0.83; Figure 3 and 4). In prairies and pastures in the United States, where the R^2 values for the plate method range between 0.70 and 0.83, which exceeds the rule method, it registers values of 0.37 for prairies and 0.59 for natural grasslands (Gangulli *et al.*, 2000). Even with low values (0.31) with the plate, in prairies in association of Gramineae - fabaceae, they exceed the capacitance meter and the graduated rule (0.31, 0.19 and 0.16, respectively) (Sanderson *et al.*, 2001). In bermuda grass var. Brazos, values of R^2=0.90 were reported for the plate, surpassing the capacitance meter (0.89) and the rule (0.86) (Gonzales *et al.*, 1990). For this study, the oat yield, var. Chihuahua, can be projected with greater reliability, by estimating the height with the plate rather than with the graduated rule (R^2=0.97 *vs* 0.83, Figures 3 and 4), since the plate combines height and density, and therefore, denser meadows present more resistance to measuring their height with the plate (Hepp *et al.*, 2017). According to Griggs and Stringer (1988) the forage yield has more correlation with the estimated height with the plate respect to that of the rule. Likewise, Hakl *et al.* (2012) indicate that alfalfa (*Medicago sativa*) has a better coefficient of determination of height with a plate (R^2=0.72), than with the rule (R^2=0.53).

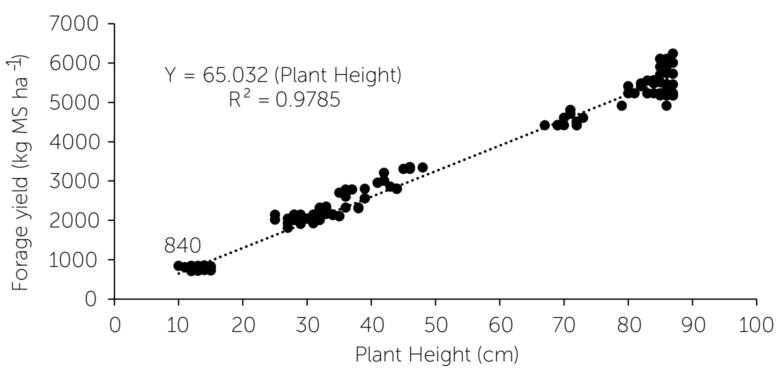

Figure 4. Linear regression between compressed heights (X) obtained with the plate method and yield (Y) in oat (*Avena sativa* L.) var. Chihuahua, harvested at different plant ages. The slope of the line was statistically different from zero (P<0.05) but not the intercept (P>0.05).

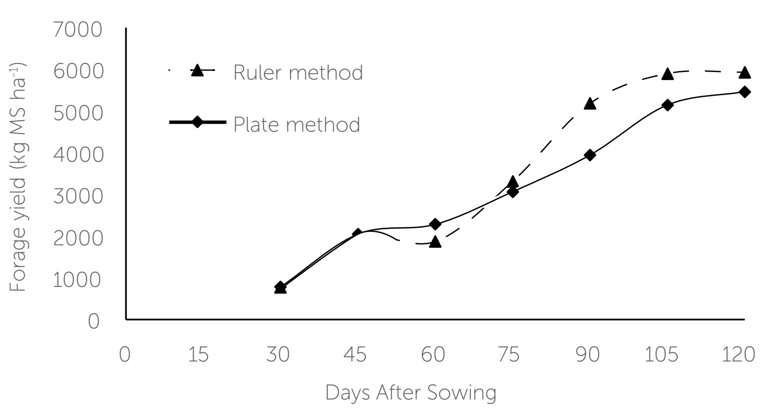

Figure 5. Average dry matter yields (Y) predicted with the ruler and plate methods, in oat (*Avena sativa* L.) var. Chihuahua, harvested at different plant ages. The slopes of the lines were statistically different from zero (P<0.05) but not the intercepts (P >0.05).

Predicted yields of heights with the ruler and plate methods

Figure 5 shows the predicted values of the dry matter yield in out (*Avena sativa* L.), var. Chihuahua, harvested at different plant ages. From 30 to 45 DAS, the results from both methods were statistically similar (p>0.05). Subsequently, the equation obtained with the plate height was closer to the yield with the direct method, explained by the higher positive correlation between these two variables due to the higher coefficient of determination (R^2=0.97) (Figure 4). The highest predicted yields were recorded in both methods at 120 DAS, with 5,922 and 5,595 kg DM ha^{-1} respectively. These were significantly different (p<0.05) from those recorded at the beginning of the study (1,035 and 806 kg DM ha^{-1}, at 30 DAS). Castillo *et al.* (2009) indicate that the higher the plant, the higher the obtained forage production is. In this study, due to the age of the plants, its height and the RMS increased in each method; however, with the rule there were higher heights, but the correlation coefficient was lower (R^2=0.83; Figure 3), which reflects a less reliable method respect to the plate. Hodgson (1999) mentions that when the height of the pasture and the density of forage are considered, by an estimation method, forage production is evaluated in a more reliable way. This is why Ganguli *et al*. (2000) report better results with the plate than with the rule, based on a higher correlation coefficient (R^2=0.83 *vs* 0.60, respectively).

CONCLUSIONS

The behavior of the accumulation curve of oats (*Avena sativa* L.) var. Chihuahua, varied as a function of the plants age. As the age of the plants increased, the forage yield increased up to 105 days after sowing. It is stated that the yield of the evaluated variety can be reliably estimated from the height with the plate method; however, further evaluation is required to better train the models. However, the height kept a high correlation with the forage yield, so it can be used as a practical criterion to determine the optimum harvest point of *Avena sativa* L. var. Chihuahua

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