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Impact of the precipitation on yield and chemical composition of oat (*Avena sativa* L.) hay forage grown in the northwestern Chihuahua, Mexico

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ABSTRACT

Objective: Assess yield and quality of oat (*Avena sativa* L.) hay growing under five rainfall scenarios: optimal, 503 mm (R-101%); middle, 277 mm (R-55%) and 260 mm (R-52%); critical, 180 mm (R-36%) and 140 mm (R-30%) of precipitation in northwestern of Chihuahua, Mexico.

Design/Methodology/Approach: The data corresponds to a previous study of oat varieties planted under rainfed conditions and harvested at dough grain maturity stage. The data analyzed employed the analysis of variance. The variables dry matter yield (DMY), total digestible nutrients yield (TDNY), relative feed value (RFV), crude protein yield (CPY), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were studied.

Results: Yield and chemical content differed significantly ($P<0.001$) by the effect of rainfall scenario The DMY and TDNY decreased as much as 43.5 and 41.6% in oats grown under critical rainfall scenario respect to an optimal rainfall scenario ($P<0.001$). Likewise, NDF, ADF and ADL contents decreased ($P<0.001$) by 5, 10 and 13%, respectively. The CP content varied due to the rainfall scenario ($P<0.001$), but it was not correlated with this factor ($r=0.218$, $P=0.069$).

Study Limitations/Implications: In the state of Chihuahua, oats are grown under rainfed conditions; however, the increasingly prolonged periods of drought make it necessary to develop and evaluate new drought-resistant oat varieties.

Findings/Conclusions: In this region, oats grown under rainfall scenarios of up to 52% of the optimal (500 mm) yield acceptable amounts of dry matter with sufficient nutritive value for feeding cattle.

Keywords: cereals, climate change, digestibility, drought, fodder, precipitation, rainfed.

INTRODUCTION

Whole plant oat (*Avena sativa* L.) hay is an excellent source of forage used in livestock feed in many regions of the world. In Mexico, oats are mainly grown under rainfed conditions (96%) and, of the total area established, 93.5% is for fodder production (SIACON, 2023).

The state of Chihuahua, Mexico, ranks first in cultivating this grass, whose contributions in 2022 were 31.2% of the national total (SIACON, 2023). In the State, 18.5% of the total area used for crops is used to grow fodder oats; and of the main fodder crops, the area sown with oats accounted for 48.8% (INEGI, 2023). Oats are mainly grown in the northwestern of the State under rainfed conditions (96%). In this region, oats are traditionally harvested for fodder at the physiological maturity stage. The oat hay produced is the main source of forage used in the feeding of dairy and beef cattle in the region (Avila *et al.*, 2006; Villazon *et al.*, 2017).

In this region of the State, climate change is affecting agricultural production (Villazon *et al.*, 2017). Changed precipitation conditions is one of the major climate factors affecting crop production (Neenu *et al.*, 2013). The scarcity and irregular distribution of the rainfall have an impact on the yield and quality of the oat crop (Kim *et al.*, 2005; Kim *et al.*, 2006). Consequently, variation rainfall scenarios can have an impact on oat forage yield and quality. In a research, Kim *et al.* (2005) found significant differences between locations on yield and forage quality of rye. They attributed higher DM and TDN yields to higher precipitation, 70 and 44.5% more, respectively. Also, Mut *et al.* (2018) observed significant differences in oat yield, with a range of 6.67 to 12.27 t ha^{-1} of hay. Under three rainfall scenarios: normal, 30% decrease in rainfall and 30% increase in rainfall, Lai *et al.* (2022) found that with normal rainfall DM yield values of soybean, oat, and vetch were 3,617, 5,284 and, 2,631 kg ha^{-1} but increased 26.2, 13.2 and 26.4%, respectively, when rainfall was increased 30%. In a subsequent publication, Lai *et al.* (2024) concluded that the forage and wheat grain production are strongly related to precipitation and increasing precipitation significantly enhanced production.

For local farmers in Chihuahua, growing rainfed oats is the last alternative when weather conditions make it impossible to plant corn in April or beans in June. Growth and production of this cereal are directly related to temperature and rainfall (Amado *et al.*, 2000; Jurado *et al.*, 2016). In this region, for oat forage production, rainfall above 500 mm is considered favourable; intermediate rainfall, 300 mm; and critical rainfall below 200 mm (Salmeron *et al.*, 2003; Jurado *et al.*, 2016). However, there is little evidence of the impact of precipitation on oat hay production and quality. Therefore, the objective was to know the productive behaviour and nutritional quality traits of oat hay by effect of rainfall scenarios, grown in the northwestern of the state of Chihuahua, Mexico.

MATERIALS AND METHODS

Experimental locations

The data used for this study corresponds to a previous study in which seven oat varieties were sown under two planting systems at five localities in northwestern Chihuahua state (in the Baja Babicora, the main oat-producing area in Mexico). The localities were: Teseachi-Namiquipa (28° 53' N, 107° 25' W), Santo Tomas-Guerrero (28° 33' N, 107° 30' W), Chopeque-Cusihuiriachi (28° 14' N, 106° 50' W), Santa Ana-Guerrero (28° 33' N, 107° 30' W) and Lazaro Cardenas-Cuauhtemoc (28° 25' N, 106° 52' W). Sowing dates at each location were: Jul-28, Jul-23, Aug-02, Jul-25 and Aug-02, 2005, respectively.

Experimental design

Hay yield and chemical composition data corresponding to the seven oat varieties sown under two planting systems, made a total of fourteen observations. Those oat varieties were growing under five rainfall scenarios (according to locality): 503 mm (R-101%) which corresponds to 500 mm of precipitation in the growing of the oat crop, considered as optimal or favourable; 277 mm (R-55%) and 260 mm (R-52%), considered as middle; 180 mm (R-36%) and 140 mm (R-30%), considered critical for this region of the state of Chihuahua (Salmeron *et al.*, 2003; Jurado *et al.*, 2016). All oats were harvested at dough grain stage (78±4 d). The sowing density was 100 kg ha^{-1} of seed, and the fertilization rate was 30-40-00 kg ha^{-1} of N-P-K. The data were distributed in an experimental arrangement completely randomized design, where oat varieties were the replications.

Dry matter and haymaking process

Dry matter yield (DMY) per hectare was determined by throwing a one-meter square five times. All oat plants within the square were cut and weighed, then the material was left in the plot for ten days to simulate the haymaking process. Drying was completed in an oven at 60 °C for 24 h to calculate the dry matter yield per hectare. The samples were then ground to 1 mm in a Wiley® mill (Arthur H. Tomas, Philadelphia, PA, USA).

Variables studied

Total dry matter (method # 930.15), ash (method # 942.05) and crude protein (CP, method # 990.03) were determined in the samples according to AOAC (1995) procedures. In addition, the cell wall fractions neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined. NDF analysis was carried out using Na_2SO_3 and α-amylase. ADL analysis was performed in a beaker by immersing the samples in a 72% H_2SO_4 solution. These fractions were determined sequentially on the Ankom200® fibre analyser using Ankom F57® bags, following the procedures proposed by the company (Ankom Technology, Fairport, NY, USA). Additionally, the relative feed value (RFV) of the forage samples was calculated using the following simplified equation:

$$RFV = \left(88.9 - (0.779 \times FDA) \times (120 / NDF)\right) / 1.29$$

(Cherney and Parson, 2020), as well as total digestible nutrients (TDN), by:

$$TDN = 88.9 - (0.79 \times ADF)$$

(Holland *et al.*, 1990). The TDN and CP results were multiplied by the DMY per hectare to obtain the TDN and CP yield per hectare.

Statistical analysis

Data were analysed with the GLM procedure using the SAS statistical software package (SAS, 2006) employed the analysis of variance (ANOVA). Each variable was analysed separately, in a univariate way. Means were compared using the least significant difference (LSD, $P \leq 0.05$) test. Pearson's correlation coefficients (r) analysis was also carried out among the variables studied, considering as important those that were significant at $P \leq 0.05$.

The following statistical model was used:

$$Y_{ij} = \mu + R_i + E_{ij}$$

Where Y_{ij} = response variable measured in the *j*-th repetition that received the *i*-th treatment, μ = overall mean, R_i = treatment effect *i*, E_{ij} = random error.

RESULTS AND DISCUSSION

Dry matter and nutrient yield variables

DMY and TDNY showed a rainfall effect. The highest DMY and TDNY were found in the optimal rainfall (R-101%), followed by the scenario R-55%. The lowest yields were found at R-36% and R-30% rainfall scenarios (Figure 1), this corresponds to 43.5% and 41.6% less DMY and TDNY with respect to the optimal rainfall scenario (R-101%), respectively.

Crude protein yield (CPY) showed a quadratic trend with respect to rainfall scenario ($P < 0.0001$). CPY was highest at R-101%, followed by R-55% and R-30% rainfall scenarios (543, 363 and 319 kg ha^{-1}, respectively). The lowest CPY was at R-52% scenario, a reduction of 58.2% with respect to the optimal rainfall scenario (Figure 2). For relative feed value (RFV), the highest values occurred at critical rainfall scenarios (128 and 129), and the lowest values were at the optimal and middle (117, 111 and 113), for R-36%, R-30%, R-101%, R-55% and R-52%, respectively (Figure 2).

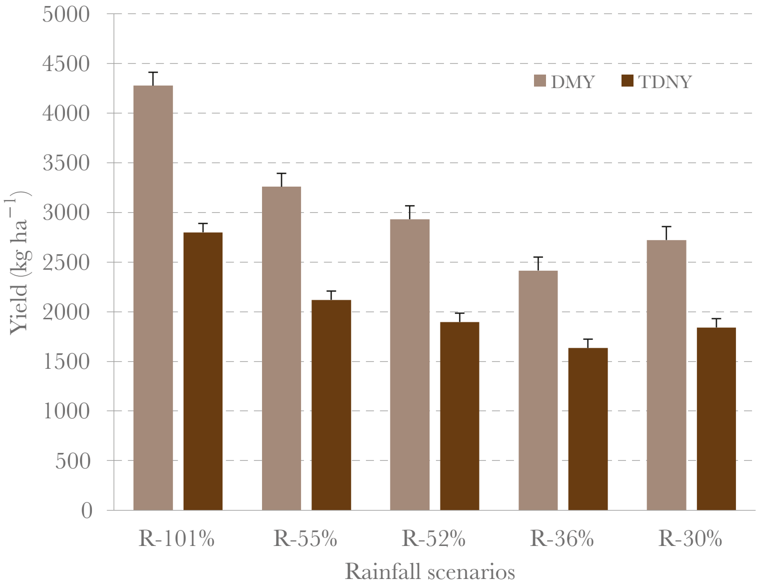

Figure 1. Dry matter yield (DMY) and total digestible nutrients yield (TDNY) of oats hay growing under different rainfall scenarios in the northwestern of Chihuahua, Mexico.

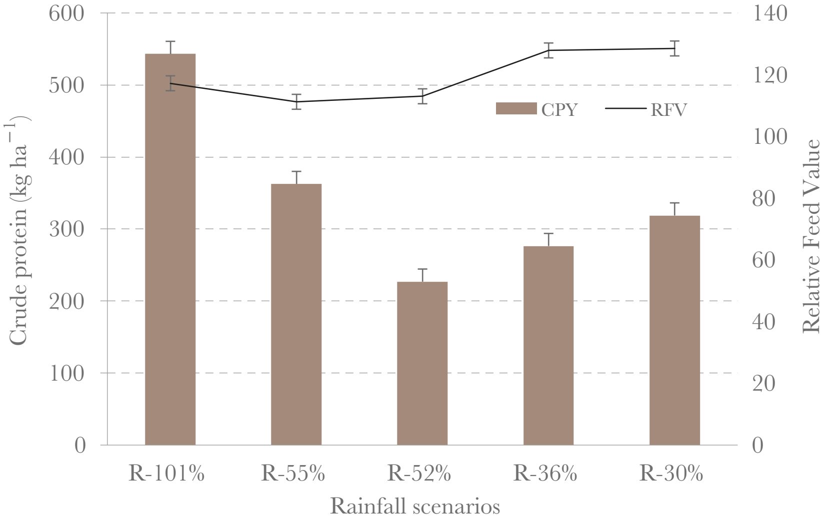

Figure 2. Crude protein yield (CPY) and relative feed value (RFV) of oats hay growing under different rainfall scenarios in the northwestern of Chihuahua, Mexico.

Chemical composition variables

Crude protein (CP) content of oat hay was highest ($P<0.001$) at R-101%, followed by R-30%, and middle at R-55% and R-36%, and lowest at R-52%. The most important statistical difference was among R-101% and R-52% rainfall scenarios, with a decrease of 38.4% less PC at R-52% compared to R-101% (Table 1).

Respect to neutral detergent fiber (NDF) and acid detergent fiber (ADF) content, the lowest values were at rainfall critical scenarios (R-36% and R-30%), and the highest values were at optimal and middle scenarios (R-101%, R-55% and R-52%), with a difference of 5.1 and 3.9 units between the highest and the lowest value for NDF and ADF, respectively (Table 1). The lignin (ADL) content showed a similar trend to NDF and ADF, with the lowest values at R-36% and R-30% and the highest values at R-101%, R-55% and R-52% (Table 1). It is interesting to note the low values of NDF, ADF and ADL in oat hay at R-36%

Table 1. Chemical composition of oats hay growing under different rainfall scenarios in the northwestern of Chihuahua, Mexico.

Rainfall scenarios	Chemical composition (% of DM)			
	CP	NDF	ADF	ADL
R-101%	12.7^{a}	52.3^{b}	29.7^{a}	3.01^{a}
R-55%	11.2^{b}	54.8^{a}	30.2^{a}	2.69^{bc}
R-52%	7.8^{c}	53.9^{ab}	30.6^{a}	2.81^{b}
R-36%	11.5^{b}	49.7^{c}	26.7^{b}	2.39^{d}
R-30%	11.8^{ab}	49.5^{c}	26.8^{b}	2.61^{c}
SEM	0.4	0.8	0.5	0.10

SEM = standard error of the mean, CP = crude protein, NDF = neutral detergent fiber, ADF = acid detergent fiber, ADL = acid detergent lignin. Rainfall scenarios: R-101% (503 mm, optimum), R-55% (277 mm), R-52% (260 mm), R-36% (180 mm), R-30% (149 mm). ^{a,b,c,d} Means with different letters within columns are different ($P<0.05$).

and R-30%, which also had low forage yields and high RFV values, may be a consequence of lower biomass production in plants, requiring less fiber (cell walls) to support the biomass weight, as Jehangir *et al.* (2013) reported similar behaviour with oats.

The correlation analysis showed a significant positive correlation between the rainfall scenario and the yield (DMY, TDNY, CPY) and chemical composition (NDF, ADF, ADL) variables, and a negative correlation with the RFV variable, while the CP content showed no effect (Table 2).

Dry matter and nutrient yield variables

Dry matter yield and nutrients per harvested area are main indicators to assess the productivity of a forage crop (Ojeda *et al.*, 2018; Lai *et al.*, 2022; Lai *et al.*, 2024). TDN is the nutrients available to livestock and is related to the concentration of ADF present in the forage: as ADF increases there is a decrease in TDN (Mut *et al.*, 2015).

Like others (Ramos *et al.*, 2011; Lai *et al.*, 2022), in this study precipitation significantly impacted DMY and TDNY per harvested area (Figure 1). In this regard Kim *et al.* (2005; 2006) observed a significant effect of locality on DMY, but they attributed higher DM, CP and TDN yields to air temperature rather than precipitation. We found that the higher yield was due more to precipitation since it was more variable than temperature. The exception was at R-52%, which, compared to R-30%, had lower precipitation, but similar DMY and TDNY (Figure 1). It is possible that factors other than rainfall influenced this result in these localities, as has been suggested by others (Kim *et al.*, 2006; Mut *et al.*, 2018). It is widely documented that the absence of rainfall induces slow or null plants growth (Ramos *et al.*, 2011). In the study by Ramos *et al.* (2011), more and better rainfall distribution was observed in 2006 compared to 2007; consequently, forage production was much higher in the first year (5,000 and 1,500 kg ha^{-1} of DM, respectively); however, they also attributed this result to the delayed sowing date and a period of low temperatures in 2007. Similarly, Lai *et al.* (2024), in four growing seasons and three rainfall scenarios (normal, −30% and +30%), observed a significant impact of precipitation on the forage yield of oats harvested at flowering stage. The oat biomass ranged from 3.66 t ha^{-1} in −30% scenario to 7.66 t ha^{-1} in +30% scenario. In 2017-2018

Table 2. Correlation coefficients between quality components of oat hay and rainfall scenarios.

Quality components	Rainfall scenario	DMY	TDNY	RFV	CPY	CP	NDF	ADF
DMY	0.769***							
TDNY	0.749***	0.994***						
RFV	−0.335**	−0.330**	−0.235**					
CPY	0.729***	0.846***	0.869***	−0.051				
CP	0.218	0.142	0.191	0.400***	0.636***			
NDF	0.265*	0.282*	0.187	−0.990***	0.026	−0.373**		
ADF	0.417***	0.375***	0.278*	−0.976***	0.060	−0.442***	0.948***	
ADL	0.563***	0.522***	0.466***	−0.585***	0.364**	−0.087	0.550***	0.667***

*Significant at P≤0.05, **Significant at P≤0.01, ***Significant at P≤0.001.

growing season, with a normal rainfall of 339 mm, dry 238 mm (−30%) and excessive wet of 441 mm (+30%), the biomass of oat in +30% scenario was increased by 16.6% compared to the normal scenario. They also found that the forage oat production shown to be strongly related to period precipitation, with a correlation coefficient $R^2=0.80$ ($P<0.001$).

Cereal forage yield depends on the influence of genetic (species, variety, or genotype), climatic (temperature, water availability, rainfall distribution, daylight hours, growing season), agronomic (fertilisation type, tillage, planting system, plant density), soil (fertility, structure, texture) factors present in a region or locality (Shah *et al.*, 2015: Lucio *et al.*, 2022). The presence, degree of influence and interaction of these factors in the crops growing season impacts forage yield and quality (Espitia-Rangel *et al.*, 2012). For example, under rainfed conditions, the amount and distribution of precipitation has a strong impact on oat yield (Sanchez *et al.*, 2014). Consequently, significant variations in yield are expected, so forage yield is a function of rainfall (Table 2). Oat producers in northwestern Chihuahua agree drought is the main problem limiting oat yield production in the region (Avila *et al.*, 2006).

In the northwestern state of Chihuahua, under good rainfed conditions, forage yields of oats harvested at physiological maturity (~92 d) exceed 5000 kg ha^{-1} of DM (Salmeron *et al.*, 2003; Avila *et al.*, 2006), while in poor to bad rainfed conditions yields range from 1000 to 3000 kg ha^{-1}, with an average of 2800 kg ha^{-1} for the three rainfall scenarios (Avila *et al.*, 2006). In the High Valleys of Mexico, in oats harvesting at dough grain stage and growing under good rainfed conditions, yields ranged from 9223 to 19454 kg ha^{-1} of DM (Espitia-Rangel *et al.*, 2012). In Zacatecas, Sánchez *et al.* (2014) observed yields of 2712 to 4764 kg ha^{-1} of DM and 46.2 to 56.4% TDN in oats harvesting at milky-dough stage. In other latitudes of the world, yields of 3312 to 6826 kg of DM and 2050 to 4283 kg ha^{-1} of TDN, at heading stage (Kim *et al.*, 2006); 6530 to 7760 kg ha^{-1} DM, at 50% flowering stage (Jehangir *et al.*, 2013); and, 1470 to 5484 kg ha^{-1} DM, at milky stage (Ramos *et al.*, 2011) are reported. This wide variation in oat forage DMY and TDN influenced by variation in days to cutting (Mendoza-Pedroza *et al.*, 2021) and by environment-genotype interaction (Ramos *et al.*, 2011; Espitia-Rangel *et al.*, 2012; Jehangir *et al.*, 2013; Mut *et al.*, 2018) mainly. On the other hand, under irrigated conditions, yields of 5355, 5800 and 8720 kg ha^{-1} DM were reported in Mexico (Sosa-Montes *et al.*, 2020: Lucio *et al.*, 2022; Solano *et al.*, 2022, respectively).

Regarding CPY, Kim *et al.* (2006) reported a CPY of 1022 to 799 kg ha^{-1} at 393 and 52 mm of rainfall when oats were harvested between the milk to dough grain stages. In Mexico, Sanchez *et al.* (2014) reported a range of 315 to 544 kg ha^{-1}, based on the variety. Mendoza-Pedroza *et al.* (2021) obtained a range of 380 to 600 kg ha^{-1} as a function of days to cutting, with the highest CPY at 75 d and then decreasing as days to cutting increased. In both studies the CPY values are alike to those obtained in this study, particularly at R-101%. We found that the CP content in oat hay trend to be low at dough grain stage, the inverse occurs with the DMY; therefore, the higher CPY observed is largely attributed to the higher DM production, which in turn depends on precipitation.

The RFV is an index that integrates NDF and ADF values, and it is used to predict the intake and energy value of a forage and is derived from the intake and DM digestibility of the forage (Mut *et al*., 2015). In agreement with Horrocks and Vallentine (1999) forages with RFV values above 151, between 150-125, 124-103, 102-87, 86-75 and below 75 are considered as first, premium, good, standard, poor and bad, respectively. According to this classification, oats growing at R-36% and R-30% scenarios reached premium quality, while most were good (Figure 2). Kim *et al.* (2006) reported values from 119 and 141 at low (141 and 52 mm) and 96 and 89 at high (235 and 393 mm) precipitation. Also, Mut *et al.* (2018) reported values from 96 to 105 in oats stablished in three locations and growing under rainfed conditions.

Chemical composition variables

The CP content changed largely by rainfall scenario effect (Table 1). In the study by Kim *et al.* (2006), showed a significant effect of precipitation on CP content; in general, CP content in oat forage decreased with higher precipitation and increased with lower precipitation. We found a similar trend from the R-52% rainfall scenario (Figure 2). It could be that the rainfall above ~250 mm increases the CP content because of major regrowth of the plant, and below 250 mm the increase of CP is due to dilution effect of the fiber components. Mut *et al.* (2018) presents significant differences between locations from 8.6 to 11.9% of CP in oat hay harvested at the milk to dough grain stages; however, it is likely that this variation in CP content is due to the other factors since rainfall behaviour showed little variation between localities and years. In Mexico, Mendoza-Pedroza *et al.* (2021) reported 14.7% at 75 d at cutting. Finally, Sanchez *et al.* (2014) observed similar values ($P>0.05$) among the oat varieties they evaluated, ranging from 11.3 to 13.2%.

Cell walls fractions NDF, ADF and ADL showed a similar trend. With favourable rainfall scenarios (R-101%, R-55%, R-52%) these cell walls components were higher, while in less favourable rainfall scenarios (R-36%, R-30%) these tended to decrease (Table 1). As mentioned above, this could be a result of lower biomass production in plants, consequence of a lower precipitation, leading to a lower deposition of these structural carbohydrates required to support the biomass weight. In addition, a fiber dilution effect has been reported due to the onset of starch filling of the kernel and the amount of grain produced by the plant at this maturity stage (Khorasani *et al*., 2007), an event that starts with the grain development stage (Rosser *et al*., 2013; Zhang *et al*., 2023); moreover, it coincides with a gradual decrease in the leaf-stem ratio and an increase in the panicle-leaf-stem ratio (Khorasani *et al*., 1997). All this leads to a change in the proportion of structural and non-structural carbohydrates on the whole oat plant.

A study found that the NDF and ADF contents in oat during the spring season (higher rainfall) were significantly higher compared to during the autumn season (lower rainfall), ranged from 62.4 to 46.1% for NDF and from 37.4 to 24.9% for ADF, respectively (Kim *et al*., 2006). On the other hand, Mut *et al.* (2018) reported 53.0 to 63.0% for NDF and 31.5 to 39.4% for ADF at three locations. In Mexico, Sanchez *et al.* (2014) and Mendoza-Pedroza *et al.* (2021) reported similar values for NDF (51.3 to 61.1% and 51.1 to 59.6%, respectively) and for ADF (34.9 to 42.7% and 29.9 to 34.9%, respectively) in oats cut between the milk-dough grain stages. The above values are close to those observed in this study. For ADL, Mendoza-Pedroza *et al.* (2021) obtained 1.8-1.9% in oats harvested at 75 and 90 d, respectively. In the study by Mendoza-Pedroza *et al.* (2021), there was an increase in fiber content with increasing days to cutting.

The values of NDF, ADF, and ADL found in this study are close to those reported by Ramos *et al.* (2011) (54.0, 29.2 and 2.9%, respectively) in oat harvested at milky stage. In the other hand, in the Ramos *et al.* (2011) study, as well as in the study by Mendoza-Pedroza *et al.* (2021), the cell walls fractions increased in the forage as maturity advanced.

Oat forage quality is a function of dry matter yield per harvested area and its chemical composition (protein, soluble carbohydrates, and fiber). The stage of maturity at cutting is a factor that has a strong impact on quality (Liu and Mahmood, 2015). At early growing stages, oat hay is favoured for high protein and soluble carbohydrate content and low fiber content, but low dry matter production. The opposite occurs when oats are cut at later stages of maturity. As a result, it has been proposed that for optimum digestible nutrient production, oats should be harvested at the milk to dough grain stages; however, it has been observed that after the dough grain stage, digestible nutrient production can be significantly higher (Zhang *et al.*, 2023), as was the case in this study when harvesting at dough stage compared to other trials where oats were harvested at an earlier maturity stage (Kaur and Goyal, 2017; Favre *et al.*, 2019; Kilicalp and Turk, 2023). This implies that, under good rainfall conditions, fertilization, and adequate tillage technique, in northwestern Chihuahua oats can be harvested between the dough grain and physiological maturity stages in order to obtain the maximum yield of digestible nutrients.

The results of correlation analysis (Table 2) showed that DMY and TDNY are strongly correlated with the amount of rainfall during the growing season of oat. Likewise, cell wall fractions (NDF, ADF, ADL) were correlated with amount of rainfall. The RFV variable showed a negative correlation with the amount of rainfall; that is, the more rainfall RFV tends to decrease, this is expected since RFV is dependent on the variables ADF and NDF. On the other hand, CP content showed no correlation with rainfall but was negatively correlated with NDF and ADF fractions. These results confirm that when these fiber fractions increase, CP content decreases, and the correlation between CP and ADL tends to be low or null.

Finally, even when oats were grown under a middle rainfall scenario of R-52%, DMY (2931 kg ha^{-1}) was higher than the average of 2800 kg ha^{-1} recorded for this region of the state (Avila *et al.*, 2006). Likewise, under this scenario de CP, NDF, ADF and ADL were 7.8, 53.9, 30.6 and 2.81%, which means acceptable digestible nutrient yields and oat forage quality.

CONCLUSIONS

In the northwestern state of Chihuahua, under rainfed conditions, oat hay yield and quality are severely affected by rainfall scenarios. The dry matter and total digestible nutrients yields decrease as much as 43.5 and 41.6% in oats grown under critical rainfall scenario with respect to an optimal rainfall scenario. Likewise, NDF, ADF and ADL contents decreased by 5, 10 and 13%, respectively. The CP content varied due to the rainfall scenario, but it was not correlated with this factor. Furthermore, it was confirmed that a decrease in CP content implies an increase in NDF and ADF contents. In this region, oats grown under rainfall scenarios of up to 52-55% of the optimum (500 mm), yield acceptable amounts of dry matter with sufficient nutritive value for feed cattle, as observed in this study.

CONFLICT OF INTEREST

All the authors declare that they have no conflicts of interest.

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