Original Research Article

Agronomic yield, digestibility, and protein content of nine alfalfa (*Medicago sativa* L.) varieties in Central Valley Oaxaca, Mexico.

ABSTRACT

The aim of the present study was to evaluate the yield, digestibility, and protein content of nine varieties of alfalfa (Medicago sativa L.). The varieties of alfalfa were compared during a complete production cycle.A completely randomized design was used taking into account the season of the year as a block and the varieties as treatment, aTukey test was used to evaluate differences between treatments. The highest dry matter (DM) production was in the summer, withAtlixco variety being the highest yield (1953.3 kg DM cut^{-1}), the ratio leaf:stalk (L:S) was highest during the winter, with no differences ($p>0.05$) between varieties. The varieties with highest protein content (PC) was Caliverde and Valenciana (22.9 % PC) during the winter ($p<0.05$). The highest digestibility was in the summer and there were no differences between varieties. The higher amount of digestible dry matter (DDM) and PC were produced by Valenciana (1586.7 kg DDM cut^{-1} and 446.7 kg PC cut^{-1}), UC-Cibola (1557.0 kg DDM cut^{-1} and 432.3 kg PC cut^{-1}) and Atlixco (1549 kg DDM cut-1 and 441.1 kg PC cut-1). The highest dry matter production was during the summer and spring, the three most productive varieties were Valenciana, Atlixco and UC-Cibola, and therefore these are the most suitable varieties for the best quality forage production in the region of study.

Keywords: Alfalfa; Yield, Digestibility, Protein content.

1. INTRODUCTION

Alfalfa (Medicago sativa L.) is the most important perennial leguminous fodder in the world, its is cultivated in more than 80 countries, approximately 30% of the occupied surface by leguminous itis dedicated to alfalfa [1], it is one of the most important feed for ruminants, for its nutritional quality it is one of the main ingredients for dairy cattle [2, 3]. Alfalfa it´s known as the “queen of forages” because of its high dry matter yield, digestibility, high protein, vitamin and mineral content [4]. It’s used as a soil remedy, due to its capacity to modulate de nitrogen and carbon cycle, helping to reduce the greenhouse gas emissions, it has a deep root system that allows it to grow well in marginal conditions without fertilization including

semi-arid lands and with limited irrigation [5]. Its agronomic performance has been evaluated in many studies to ensure high productivity considering cut interval and the season of the year, also the speed of resprout between cuts and the remain leaf area is fundamental to understand the effect of frequency and intensity of the forage yield [6]. On the other hand, Montes [7] andRojas [8] report a high growth rate in alfalfa in spring and summer seasons, and less growth in the fall and winter in cold weather in the Mexico Valley. However, Villegas[9] obtained a high growth rate of two varieties of alfalfa in in spring, followed by the winter, summer and the lowest growth rate in the fall in the Oaxaca Valley. Rivas [10] and Zaragoza [11], without considering interval yields, obtained higher yields for alfalfa in spring-summer, than in the winter. Villegas [9] obtained the highest yield with two varieties in spring, winter and summer and the lowest production in the fall. All of the carried out studies have created a great technical knowledge about alfalfa biology, which in turn lead in the development of new varieties that can grow in different environmental conditions and management [33-35]. In Mexico many studies about productive variables of alfalfa have been performed, however, there is not a definition of which varieties would be more appropriated for each region. For all the above mentioned, the aim of the present study was to evaluate yield, digestibility and protein content of nine alfalfa varieties, in the Oaxaca central Valleys, Mexico.

2. MATERIAL AND METHODS

2.1. LOCALITATION

The experiment was carried out during the 2018 production cycle in the fields of the unit dairy production facility of Nazareno, Etla Oaxaca, at 17º13´ N and 96º48´W at 1641 meters above sea level inside the region named Oaxaca Central Valley, Mexico, with a semi warm weather with isothermal fresh summer (A)C(W”o)(W)b(i´)g, with an average annual temperature 19.2^{o}C and average annual rainfall 667 mm [12]. The predominant soil type in the region is cambisolcalcium [13].

2.2. Plot management

Four 5×5 m sampling plots were randomly established; the prairie was in the second-year yield, interval cut varied according to the season of the year and was established by the following way: 35 days in spring, 28 days in the summer, 35 days in the fall and 42 days in the winter, a total of 19 irrigation water periods were performed on a two-week interval between each irrigation. The varieties used were Atlixco, Caliverde, Elcamino, UC-Cibola, Moapa, NK-819, Oaxaca, Valenciana and VelludaPeruana.

2.3. Measured Variables

2.3.1. Dry matter yield

Dry matter (DM) yield per cut was evaluated using a sample unit a square of 0.25 m^2 in each alfalfa plot, taking two random samples per repetition. The fodder in each square was harvest one day before the cut, leaving a 5 cm remain height, samples were weighed in fresh, then they were washed and dried in an air force stove at a 55 ºC temperature during 72 h once the fodder sample was dried its dry weight was recorded, in order to determine the yield by surface unit (kg DM ha^{-1}).

2.3.2. Ratio leaf:stalk (L:S)

From the fresh fodder samples, 100 g were separated, from these leaf and stalk were separated to calculate the leaf:stalk ratio (LSR), and it was calculated with the following formula:

$$L:S= L/S$$

where: L= dry leaf weight (g); S= dry stalk weight (g).

2.3.3. Crude Protein

For the protein determination a Kjeldahl method [14], was used, using a 2 g ground sample dry matter, they were digested and then distilled in a micro Kjeldahl equipment; the distilled was titrated with boric acid, until it turned brilliant red, the milliliters spent were multiplied by

6.25 to obtain the protein percentage of each sample. In order to obtain the amount of protein produced, the protein percentage was multiplied by the DM kg of each sample.

2.3.4. Digestibility

For in situ digestion of dry matter (DISMS) an interval of 72 h was established [15]. With the data obtained of the digestibility percentage, data was multiplied by the DM kg of each sample of each variety, to obtain the amount of digestible dry matter digestibility (DISMS).

2.4. Weather data

Data from the meteorological station were used, Oaxaca International Airport, this station is considered reliable according to the International Standard Atmosphere[16].

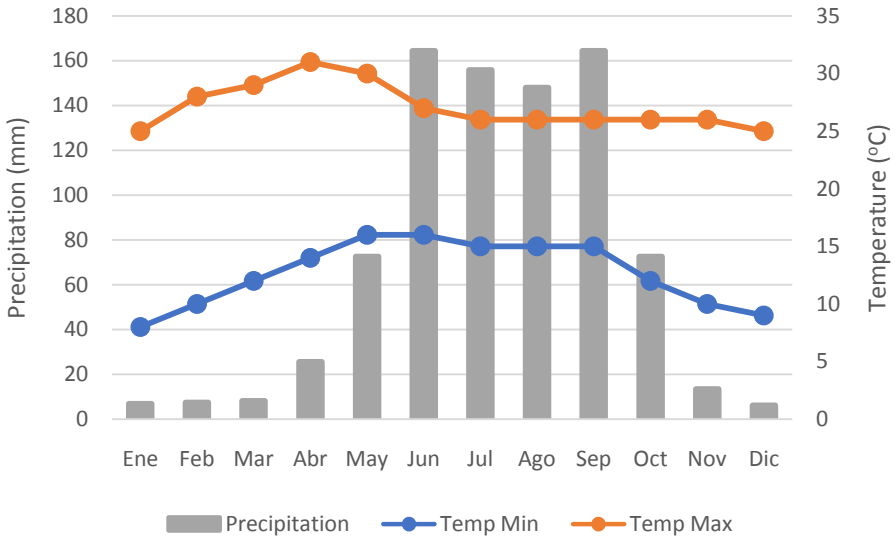

Figure 1. Monthly accumulated precipitation and minimum and maximum monthly average temperature in the Central Valleys of Oaxaca, Mexico.

2.5. Statistical Analysis

The variance analysis to analyze the effect of the alfalfa varieties used in this experiment, was performed by a mixed model procedure analysis of variance [17], with a complete random block design with four repetitions. Tukey test was used to compare means of treatments (α= 0.05) according to Steel and Torrie [18].

3. RESULTS AND DISCUSSION

3.1.DRY MATTER PRODUCTION

Average yield per cut (kg DM ha^{-1}) of the nine alfalfa (Medicago sativa) varieties in the four seasons of the year are shown In Table 1, in average they produced 2081.1 kg per cut; Atlixco, El camino, UC-Cibola, Oaxaca, and Valenciana varieties, had a similar yield ($p>0.05$) outstanding Valenciana variety, that was statistically different than Caliverde, Moapa, Velluda ($p<0.05$), NK-819 variety had a lower production ($p<0.05$); the dry matter yield per cut per season of the year had the following order: summer>spring>fall>winter.

The average production per cut was similar to the one reported by Rivas-Jacobo [10], however, the varieties Oaxaca, Moapa and Valenciana in our study had less production per cut per season than the one reported by these authors.

In a study made in the region of Valles Centrales of Oaxaca with the varieties: Moapa, Oaxaca and Valenciana by Villegas-Aparicio[19], in general the average yield was similar to our results, but it was higher in spring and summer, and during the fall and winter decreased markedly. By year season winter production was lower ($p<0.05$) and in the other seasons was similar ($p>0.05$).

The highest production per cut was achieved in the summer, where varieties Atlixco and Velluda were different to El Camino and Moapa with less yield per cut ($p<0.05$). During the winter all varieties had less production due to the decrease of temperature and light hours. The highest growth rate of alfalfa was in spring and summer with presence of optimum temperatures according with data reported by Rojas [20].

Rojas [8] obtained an average annual yield of 1505 kg of DM ha^{-1} cut^{-1} in five varieties of alfalfa in Mexico Valley, which is under the data found in our study, as regards of Atlixco variety which was also evaluated by our team, it also had a better yield per cut, however, during the summer they observed a higher yield of the mentioned variety 2072 kg DM ha^{-1}

cut^{-1}, the higher results found in our study maybe were due to more constant temperatures during the cycle of evaluation.

Table 1. Averagedrymatteryield of nine alfalfa varieties per season (kg DM ha^{-1}cut^{-1}) per alfalfa cut in the Central Valleys of Oaxaca, Mexico.

Varieties	Winter	Spring	Summer	Fall	Mean
Atlixco	$1501.1^{c}{}_{A}$	$1812.4^{b}{}_{A}$	$1953.3^{a}{}_{A}$	$1745.4^{b}{}_{BCD}$	1753.0_{AB}
Caliverde	$1554.4^{b}{}_{A}$	$1655.2^{ab}{}_{BCD}$	$1758.8^{a}{}_{BC}$	$1527.3^{b}{}_{E}$	1623.9_{BC}
El Camino	$1199.4^{c}{}_{B}$	$1852.8^{a}{}_{A}$	$1635.5^{b}{}_{C}$	$1907.3^{a}{}_{A}$	1648.7_{ABC}
UC-Cibola	$1495.9^{b}{}_{A}$	$1764.2^{a}{}_{AB}$	$1852.2^{a}{}_{AB}$	$1797.2^{a}{}_{ABC}$	1727.4_{AB}
Moapa	$1528.5^{b}{}_{A}$	$1542.2^{ab}{}_{D}$	$1710.2^{a}{}_{C}$	$1692.7^{ab}{}_{DC}$	1618.4_{CB}
NK-819	$1375.1^{b}{}_{AB}$	$1618.7^{a}{}_{CD}$	$1764.4^{a}{}_{BC}$	$1318.5^{b}{}_{F}$	1519.2_{C}
Oaxaca	$1850.3^{b}{}_{AB}$	$1727.1^{a}{}_{ABC}$	$1850.3^{a}{}_{AB}$	$1732.2^{a}{}_{BCD}$	1699.4_{AB}
Valenciana	$1569.9^{b}{}_{A}$	$1834.9^{a}{}_{A}$	$1886.6^{a}{}_{AB}$	$1870.8^{a}{}_{AB}$	1790.5_{A}
Velluda	$1347.3^{c}{}_{AB}$	$1584.3^{b}{}_{D}$	$1932.8^{a}{}_{A}$	$1606.7^{b}{}_{EF}$	1617.8_{BC}
Promedio	1451.1^{b}	1710.2^{a}	1816.0^{a}	1688.7^{a}	1666.5

abc=Meanswiththedifferentlowercase literal per row are statisticallydifferent (p<0.05).

ABCD=Meanswiththedifferent capital letter per column are statisticallydifferent (p<0.05).

3.2. Leaf:Stalk Ratio (L:S)

In the leaf:stalk ratio (L:S) there were only differences by season in the UC-Cibola and NK-819 varieties (Table 2), the variety UC-Cibola in the fall had a lower ratio L:S ($p<0.05$) and in the winter the variety NK-819 has a higher ratio L:S ($p<0.05$), in the remain varieties de L:S was similar ($p>0.05$), during all the seasons of the year, in the winter the was the highest ratio L:S and in the summer the lowest ($p<0.05$). During the fall there were only differences between varieties, where Atlixco had the highest ratio L:S, these results are in agree with those reported by Alvarez-Vázquez [21], where in the fall the Atlixco, Oaxaca and Valenciana varieties had the highest ratio L:S.

The average L:S was different in the seasons of the year, with the higher values in the winter and fall ($p<0.05$), which are in agree with the one reported by Rojas García [22], in the summer the ratio is lower. In general, the ratio L:S is similar to the one reported by Urbano[23] in a study in the high zone of Venezuela. The L:S in our study was lower to the one reported in the fall and winter 1.46 and 1.52, but was higher to what they reported in spring and summer, 0.94 y 0.92, in general our results were more constant, during the four seasons of the year, in average the L:S was 1.27. The L:S in forages it's an indirect measure of quality, if the value is higher than one, it indicates better forage quality than the values lower than one [9, 24, 25] in our study all the varieties scored values higher than one, which indicates forage of good quality, which is related to a good digestibility and protein content.

The lower ratio L:S that was in the summer and spring it's because in these seasons the stalk growth is faster than the leaf production, decreasing de L:S which is in agreement with the one reported by Rojas[8].

Table 2.Leaf:stem ratio (L:S) of nine alfalfa varieties by season in the Central Valleys of Oaxaca, Mexico.

Varieties	Winter	Spring	Summer	Fall	Mean
Atlixco	1.42	1.19	1.25	1.66^{a}_{A}	1.38
Caliverde	1.37	1.30	1.11	1.44_{AB}	1.31
El Camino	1.39	1.31	1.09	1.15_{CB}	1.23
UC-Cibola	1.47a	1.25ab	1.15ab	0.90^{b}_{C}	1.19
Moapa	1.49	1.16	1.15	1.29_{B}	1.27
NK-819	1.37a	1.23ab	1.03b	1.30^{ab}_{B}	1.23
Oaxaca	1.32	1.28	1.28	1.26_{B}	1.29
Valenciana	1.30	1.31	1.17	1.46_{AB}	1.31
Velluda	1.39	1.12	1.10	1.26_{B}	1.22
Means	1.39a	1.24bc	1.15c	1.30ab	1.27

abc=Means with the different lowercase literal per row are statistically different ($p<0.05$).

ABCD=Means with the different capital letter per column are statistically different (p<0.05).

3.3. Protein content (PC)

The protein content is shown in Table 3, there were no differences between varieties(p>0.05). Between seasons, in the winter there was the higher protein content and, in the spring, the lowest content (p<0.05); in the summer and the fall there were no (p>0.05) differences. The Moapa, Caliverde and Valenciana varieties had a higher protein content trend in the winter and the Atlixco variety had a lower protein content in the spring. In the majority of the leguminous the green parts of alfalfa are rich in protein, and its ability to attach atmospheric nitrogen makes alfalfa an important crop for forage production and soil conservation [26].

The results in our study are similar to those obtained in a research study done in Zacatecas by Sánchez[27], who reported in average 20.1 % de PC, in the five varieties used, and below of the results obtained by Urbano[23] in Venezuela who reported a protein content of 22.7 % PC, Chocarro [28] 24 % PC in alfalfa prairies in the winter and [29] who report 25.5 % PC at 30 days cut, similar to the days of cut in our study, however, at 40 days they reported a lower content (18.4 % PC) and in our study during the winter the interval cut was 42 days the protein content was higher. The results found in our study were higher to the ones reported by Zhang [30] who evaluated twenty crops in China and their average results were 18.0 % PC.

Protein production in kg per ha was obtained from multiplying dry matter yield produced by cut by the protein content of each variety, the total production was 418.4 kg of protein per cut in all varieties, Valenciana variety was the one with more (p<0.05) production 446.7 kg of protein per cut and the variety NK-819 was the one with les production 369.0 kg protein; by season of the year, the summer had the highest (p<0.05) with 453.1 kg protein and in the spring the production was lower (p<0.05) 396.4 kg ´protein. In the summer the Atlixco variety was the one with the highest yield 488.1 kg PC and the one with lower yield was NK-819

420.2 kg protein ($p<0.05$). Alfalfa contributes to the agriculture and livestock sustainability since its used to improve vegetal coverage, and prevents prairie degradation [29].

Table 3.Protein content (%) of nine varieties of alfalfa in the Central Valleys of Oaxaca, Mexico.

Varieties	Winter	Spring	Summer	Fall	Mean
Atlixco	$22.1^{a}{}_{AB}$	$17.7^{b}{}_{A}$	$20.0^{ab}{}_{A}$	$21.1^{a}{}_{A}$	20.2_{A}
Caliverde	$22.9^{a}{}_{A}$	$18.9^{b}{}_{A}$	$20.8^{ab}{}_{A}$	$20.5^{ab}{}_{A}$	20.8_{A}
El Camino	$22.2^{a}{}_{AB}$	$18.7^{b}{}_{A}$	$21.5^{a}{}_{A}$	$20.1^{ab}{}_{A}$	20.6_{A}
UC-Cibola	$22.2^{a}{}_{AB}$	$19.2^{b}{}_{A}$	$19.7^{ab}{}_{A}$	$19.3^{ab}{}_{A}$	20.1_{A}
Moapa	$23.0^{a}{}_{A}$	$19.1^{c}{}_{A}$	$20.4^{bc}{}_{A}$	$21.2^{b}{}_{A}$	20.9_{A}
NK-819	$21.2^{a}{}_{BC}$	$18.0^{b}{}_{A}$	$19.1^{ab}{}_{A}$	$19.9^{ab}{}_{A}$	19.5_{A}
Oaxaca	$21.7^{a}{}_{ABC}$	$18.8^{b}{}_{A}$	$19.1^{b}{}_{A}$	$20.0^{b}{}_{A}$	19.9_{A}
Valenciana	$22.9^{a}{}_{A}$	$18.3^{b}{}_{A}$	$19.7^{ab}{}_{A}$	$19.4^{ab}{}_{A}$	20.1_{A}
Velluda	$20.4^{a}{}_{C}$	$18.1^{b}{}_{A}$	$19.8^{ab}{}_{A}$	$19.2^{ab}{}_{A}$	19.4_{A}
Mean	22.1a	18.5c	20.0b	20.1b	20.2

abc=Means with the different lowercase literal per row are statistically different ($p<0.05$).

ABCD=Means with the different capital letter per column are statistically different ($p<0.05$).

3.4. Dry Matter Digestibility

In average dry matter digestibility (DMD) was similar ($p>0.05$) in the nine varieties, by season of the year the winter and summer had the highest ($p<0.05$) digestibility. Atlixco, El camino, Moapa, NK-819 and Oaxaca varieties had the highest digestibility in the winter and summer (Table 4). This is because in the winter due to a low temperature the physiological maturity stops and the digestibility increases, in the summer the highest digestibility is due to the alfalfa grows faster and its harvested at a less age (four weeks) [31, 32].

The Valenciana variety had the highest ($p<0.05$) dry matter digestibility with 1586.7 kg DM/cut, higher than Caliverde, El Camino, Moapa and Velluda (1443.3, 1484.1, 1448.2 and

1435 kg respectively), the NK-819 variety had the lowest digestibility with 1327.1 kg. By season of the year the summer had the highest dry matter digestibility 1669.7 kg DMcut^{-1} and lower in the winter 1324.6 kg DMcut^{-1} ($p<0.05$). Atlixco variety in the summer had the highest production per cut 1844.1 kg DMcut^{-1} and the El Camino variety had the lowest production during the winter. These results can be due to the lower temperatures recorded in the winter that stop the physiological maturity of the forage species making them more appropriated for the digestion process [31, 32].

Table 4. Dry Matter Digestibility (%) of nine alfalfa varieties in the Central Valleys of Oaxaca, Mexico.

Varieties	Winter	Spring	Summer	Fall	Mean
Atlixco	$72.2^{ab}{}_{A}$	$65.5^{b}{}_{A}$	$75.6^{a}{}_{A}$	$69.4^{ab}{}_{A}$	70.7_{A}
Caliverde	$74.1^{a}{}_{A}$	$68.2^{b}{}_{A}$	$69.0^{b}{}_{A}$	$73.7^{a}{}_{A}$	71.2_{A}
El Camino	$73.7^{ab}{}_{A}$	$68.8^{b}{}_{A}$	$75.0^{a}{}_{A}$	$71.6^{ab}{}_{A}$	72.3_{A}
UC-Cibola	$71.1^{ab}{}_{A}$	$69.5^{b}{}_{A}$	$72.6^{ab}{}_{A}$	$74.8^{a}{}_{A}$	72.1_{A}
Moapa	$72.5^{ab}{}_{A}$	$68.7^{b}{}_{A}$	$75.4^{a}{}_{A}$	$69.9^{b}{}_{A}$	71.6_{A}
NK-819	$71.4^{ab}{}_{A}$	$66.5^{bc}{}_{A}$	$75.2^{a}{}_{A}$	$65.5^{c}{}_{A}$	69.7_{A}
Oaxaca	$75.3^{a}{}_{A}$	$73.2^{a}{}_{A}$	$75.2^{a}{}_{A}$	$66.5^{b}{}_{A}$	72.5_{A}
Valenciana	$74.5^{a}{}_{A}$	$71.1^{a}{}_{A}$	$72.9^{a}{}_{A}$	$65.6^{b}{}_{A}$	71.1_{A}
Velluda	$72.6^{a}{}_{A}$	$67.9^{b}{}_{A}$	$71.8^{ab}{}_{A}$	$71.7^{ab}{}_{A}$	71.0_{A}
Mean	73.1^{a}	68.8^{b}	73.6^{a}	69.9^{b}	

abc=Means with the different lowercase literal per row are statistically different ($p<0.05$).

ABCD=Means with the different capital letter per column are statistically different ($p<0.05$).

In terms of production and quality of the different varieties; Valenciana had (1790.5 kg DM cut^{-1}, 1586.7 kg DMD cut^{-1} and 446.7 kg protein cut^{-1}), UC-Cibola (1790.5 kg DM cut^{-1}, 1557.0 kg DMD cut^{-1} and 432.3 446.7 kg CP cut^{-1}) and Atlixco (1753.0 kg DM cut^{-1}, 1549 kg

DMD cut^{-1} and 441.1 kg CP cut^{-1}). The average highest values per cut coincide with the highest temperatures and rainfalls of the year.

4. Conclusion

The highest dry matter yield was during the spring and summer, the three most productive varieties were Valenciana, Atlixco and UC-Cibola; in the L:S ratio Atlixco was the best variety; Moapa had the highest crude protein content and the most digestible was the Oaxaca variety. In terms of dry matter digestible production Valenciana, Atlixco and UC-Cibola varieties were the highest, that is why these three varieties are the most recommended for the forage production in the study region as they have a lower environmental impact due to dry matter production and protein content.

REFERENCES

1. Peoples MB, Hauggaard-Nielsen H, Huguenin-Elie O, Jensen, ES, JustesE, Williams M. The contributions of legumes to reducing the environmental risk of agricultural production. In Agroecosystem diversity (pp. 123–143). Academic Press . 2019.
2. Gallego A, Hospido A, Moreira MT, Feijoo G. Environmental assessment of dehydrated alfalfa production in Spain. Resources, Conservation and Recycling. 2011; Volume 55, Issue 11, 1005-1012. https://doi.org/10.1016/j.resconrec.2011.05.010
3. Wang X, Kristensen T, Mogensen L, Trydeman Knudsen M, Wang X. Greenhouse gas emissions and land use from confinement dairy farms in the Guanzhong plain of China – using a life cycle assessment approach. Journal of Cleaner Production. 2016; 42(1): 577-586. https://doi.org/10.1016/j.jclepro.2015.11.099
4. Wang T, Wen-Hao Z. Priorities for the development of alfalfa pasture in northern China. Fundamental Research. 2023; 3, 225-228

https://doi.org/10.1016/j.fmre.2022.04.017

5. Yang P, Zhang P, Li B, Hu T. Effect of nodules on dehydration response in alfalfa (Medicago sativa L.). Environmental and Experimental Botany. 2013; Vol 86: 29-34 https://doi.org/10.1016/j.envexpbot.2011.05.012
6. Pérez BMT, Hernández A, Pérez J, Herrera JG, Bárcena R. Productive response and regrowth dynamics of perennial ryegrass at different cutting heights. Livestock Technique Mexico, 2002;40(3), 251-263.

https://www.redalyc.org/pdf/613/61340307.pdf

7. Montes CFJ, Castro RR, Aguilar BG, Sandoval TS, Solís, OMM. Seasonal accumulation of aerial biomass of alfalfa Var. Oaxaca Creole (Medicago sativa L.). Mexican Journal of Livestock Sciences. 2016;7(4),539-552. https://doi.org/10.22319/rmcp.v7i4.4281
8. Rojas AR, Hernández A, Joaquín S, Maldonado-Peralta M, Mendoza SI, Álvarez-Vázquez P, Joaquín-Torres BM. Productive behavior of five varieties of alfalfa. Mexican Journal of Agricultural Sciences. (2016);Vol.7 No.8: 1855-1866. https://cienciasagricolas.inifap.gob.mx/index.php/agricolas/article/view/97/90
9. Villegas Y, Hernandez A, Perez J, Lopez C, Herrera JG, Enriquez JF, Gomez A. Seasonal growth patterns of two alfalfa (Medicago sativa L.) varieties. Livestock Technique in Mexico. 2004; 42(2), 145-158. https://cienciaspecuarias.inifap.gob.mx/index.php/Pecuarias/article/view/1421/1416
10. Rivas MA, López C, Hernández A, Pérez J. Effect of three harvesting regimes on the productive behavior of five commercial varieties of alfalfa (Medicago sativa L.). Pecu. Tech. Mex. 2005; 43: 79-92.

https://www.redalyc.org/pdf/613/61343110.pdf

11. Zaragoza EJ, Hernandez-Garay A, Perez J, Herrera JG, Osnaya F, Martinez P, Gonzalez SS, Quero A. Seasonal growth analysis of an associated alfalfa-grass Ovillo meadow. Livestock Technique Mexico. 2009; 47(2), 173-1

https://www.redalyc.org/articulo.oa?id=61312116005

12. García, E. Modifications to the Koppen Climate Classification System. 4 (ed). National Autonomous University of Mexico. Mexico DF. p. 217 2004.

http://www.publicaciones.igg.unam.mx/index.php/ig/catalog/view/83/82/251-1

13. Vásquez-Rasgado PS, Rodríguez-Ortiz G. The soils of the Central Valleys of Oaxaca. Mexican Magazine of Agroecosystems. 2018;Vol. 5(2): 156-167. https://revistaremaeitvo.mx/index.php/remae/article/view/170/152

14. Association of Official Analytical Chemists, Official Methods of Analysis. 15th (Ed.). Washington, D. C. USA. 1990.

https://law.resource.org/pub/us/cfr/ibr/002/aoac.methods.1.1990.pdf

15. Mehrez AZ, Orskov EE. A study of the artificial fibre bag technique for determining the digestibility of feed in the rumen. J. Agric. Sci. 1977; 88(3):645-655. https://doi.org/10.1017/S0021859600037321

16. WeatherSpark. The weather throughout the year anywhere in the world. Climate and average weather throughout the year in Oaxaca. 2018. https://es.weatherspark.com/y/8535/Clima-promedio-en-Oaxaca-M%C3%A9xico-durante-todo-el-a%C3%B1o#Figures-ObservedWeather

17. SAS, Institute. SAS/STAT® 9.2. Use´s Guide Release.Cary, NC: SAS InstituteIcn. USA. Steel, Robert George Douglas; Torrie, James Hiram; Dickey, David A. Principles and Procedures of Statistics: A Biometrical Approach ISBN 13: 9780070610286. 2009.

18. Steel RGD, Torrie JH. Principles and Procedures of Statistics: A Biometrical Approach. Mc.Graw-Hill. Third Edition. USA. p. 642 1996;

19. Villegas AY, Hernández A, Martínez PA, Pérez PJ, Herrera HJG, López CC. Forage yield of alfalfa varieties in two cutting calendars. Rev. Fitotec. Mex. 2006; 29: 369-372.

https://revfitotecnia.mx/index.php/RFM/article/view/809/77017.

20. Rojas AR, Torres N, Joaquín S, Hernández A, Maldonado MA, Sánchez P. Yield components in Alfalfa varieties (Medicago sativa L.). Agroscience. 2017; 51(7), 697-708.

https://agrociencia-colpos.org/index.php/agrociencia/article/view/1321/1321

21. Álvarez-Vázquez P, Hernández-Garay A, Mendoza-Pedroza SI, Rojas-García AR, Wilson-García CY, Alejos-de la Fuente JI. Production of ten varieties of alfalfa (Medicago sativa L.) after four years of being established. Agroscience. 2018; 52: 841-851.

https://www.scielo.org.mx/pdf/agro/v52n6/2521-9766-agro-52-06-841-en.pdf

22. Rojas AR, Torres N, Maldonado MA, Herrera J, Sánchez P, Cruz A, et, al. Forage yield and its components in alfalfa varieties in the highlands of Mexico. Rev MexCiencPecu. 2019;10(1):239-253.

http://dx.doi.org/10.22319/rmcp.v10i1.4631

23. Urbano D, Dávila C. Evaluation of the yield and chemical composition of eleven varieties of alfalfa (Medicago sativa) under cutting in the high zone of the state of Mérida, Venezuela. Rev. Fac. Agron. (LIGHT). 2003; 20: 97-107.

http://ve.scielo.org/scielo.php?script=sci_arttext&pid=S0378-78182003000100010

24. Hernandez GA, Martinez HPA, Zaragoza EJ, Cowgirl HH, Osnaya GF, Joaquin TBM, Velasco ZME. Characterizing the forage yield of an alfalfa-egg meadow by varying grazing frequency and intensity. Mexican Phytotechnical Journal. (2012). 35(3), 259-2

https://www.scielo.org.mx/pdf/rfm/v35n3/v35n3a9.pdf

25. Morales AJ, Jimenez VJL, Velasco VVA, Villegas AY, Enriquez VJR, Hernandez GA. Evaluation of 14 alfalfa varieties with fertiriego in the mixteca of Oaxaca. Livestock Technique in Mexico. 2006; 44(3),

https://www.redalyc.org/pdf/613/61344301.pdf

26. Murphy-Bokern D, Stoddard FL, Watson CA. Legumes in cropping systems. CABI. Developing legume Cropping: Looking Forward. p. 224. 2017;

https://www.cabidigitallibrary.org/doi/pdf/10.1079/9781780644981.0000

27. Sanchez-Gutierrez RA., Servin M, Gutierrez H, Serna A. Efficiency in water use of alfalfa varieties (Medicago sativa L.) with subsurface irrigation system. Rev MexPecSci 2017;8(4):429-435 http://dx.doi.org/10.22319/rmcp.v8i4.4255
28. Chocarro C, Lledó M, Fanlo R, Lloveras J. Effect of winter grazing on the protein contents of alfalfa spring regrowth. In: Delgado I. (ed.), Lloveras J. (ed.). Quality in lucerne and medics for animal production. Zaragoza: CIHEAM. p. 253-255. 2001. https://om.ciheam.org/om/pdf/a45/01600094.pdf
29. Chen JS, Tang FL, Zhu RF, Gao C, Di GL, Zhang YX. Effects of cutting frequency on alfalfa yield and yield components in Songnen Plain, Northeast China. Afr. J. Biotechnol. 2012; 11: 4782-4790. https://doi.org/10.5897/AJB12.092
30. Zang T, Kang J, Gou W, Zhao Z, Xu Y, Yan X, Yang Q. Yield evaluation of twenty-eight alfalfa cultivars in Hebei Province of China. Journal of Integrative Agriculture. 2014;. 13(10): 2260-2267. https://doi.org/10.1016/S2095-3119(13)60576-6
31. Rafińska K, Pomastowski P, Wrona O, Górecki R, Buszewski B. Medicago sativa as a source of secondary metabolites for agriculture and pharmaceutical industry. Phytochemistry Letters. 2017 Jun 1;20:520-39. https://doi.org/10.1016/j.phytol.2016.12.006
32. Babiker SA, Khair MA, Tahir IS, Elhag F. Forage quality variations among some Sudan pearl millet [Pennisetumglaucum (L.) R. Br] collection. Annual Research & Review in Biology. 2014 Oct 14;5(4):293-8. http://www.sciencedomain.org/abstract.php?iid=239&id=9&aid=1471