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Thecnical note

Effect of the cutting height of sorghum at harvest on forage yield and nutritional value of silage

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Abstract:

The objective was to identify an optimal cutting height at harvest of sorghum forage (*Sorghum bicolor* L.) to improve the nutritional quality of silage, without reducing the dry matter (DM) yield of the forage. The effect of cutting height at 10, 20, 30, 40, 50 and 60 cm on DM yield and nutritional value of silage was evaluated. The forage was harvested when the grain reached a milky-dough state. The plants were crushed to a particle size of 2 cm and the forage was compacted to 261 kg of MS/m^3 in mini silos. The DM yield reduced from harvesting at 40 cm above the ground. The neutral detergent fiber (NDF) and lignin of silage were superior when harvested at 10 cm, but lignin reduced by 1.4 % when the cut was greater than 20 cm. The NDF digestibility and total digestible nutrient (TDN) concentration increased when harvested at 40 cm. The highest content of non-fibrous carbohydrates (NFC) was obtained when harvested at 40 and 50 cm. The net lactation energy (NLE) of silage increased from harvesting at 20 cm. The optimal pH of silage was obtained when harvested at 30 cm. In conclusion, harvesting the sorghum fodder between 20 and 40 cm allows obtaining a silage with lower lignin content and, therefore, greater digestibility and energy concentration without negatively affecting the DM yield of the forage.

Key words: *Sorghum bicolor* (L.), Dry matter yield, Silage, Cutting height, Nutritional value.

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Forage sorghum is a viable alternative for producing silage on dairy farms located in regions with arid and semi-arid environments. This crop has been shown to grow well under conditions of limited water [(1)] and high temperatures[(2)]; in addition to having moderate tolerance to soil salinity[(3)]. Under these conditions, sorghum has the advantage of being able to produce larger amounts of dry matter (DM) compared to forage maize[(4,5)]. However, the lignin content in the forage of conventional sorghum varieties (up to 9.1 % of DM) is associated with silages that have low NDF digestibility (NDFD); therefore, when used in the diets of dairy cows, it limits the consumption of DM and milk production[(6,7)].

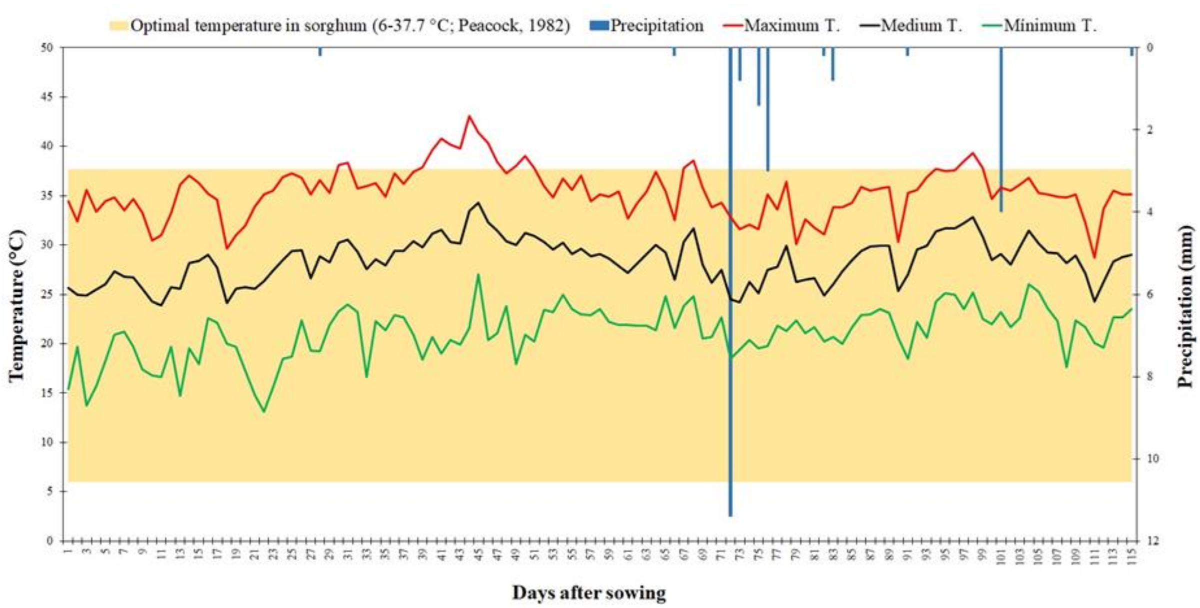
A practical option to reduce lignin concentration and improve the digestibility of the silage fiber of different forages is to increase the cutting height. In this regard, it has been reported that increasing the cutting height from 15 to 45 cm in black sorghum (*Sorghum almum*) reduces lignin contents from 7.7 to 6.4 %[(8)]. In forage maize, it was found that lignin decreased from 3.0 to 2.6 %, while NDFD increased 2.3 % when cutting height at harvest increased from 12 to 45 cm[(9)]. Similarly, the increase in cutting height in forage maize from 15 to 45 cm increased NDFD by 5.0 %, which was attributed to decreasing the proportion of basal stems containing the most lignified part of the plant[(10)].

When the cutting height of the forage increases, the nutrient composition of silage improves; however, DM yield losses can become very significant if very high cutting heights are used. The above causes that this harvesting strategy is not accepted by producers. Yield losses in DM of sorghum forage can be between 10 and 20 % when increasing the cutting height above 20 cm[(11,12)] and from 3 to 16 % when increasing the cutting height to more than 40 cm in forage maize(10,13). Therefore, it is necessary to identify the best cutting height in forage sorghum, which allows having an optimal balance between the nutritional composition of silage and the DM yield per hectare at harvest. The objective of the present work was to identify the optimal cutting height in forage sorghum to improve the nutritional quality of silage without affecting the DM yield.

The experiment was established during the spring 2018 production cycle in the Ejido Venecia, located in the Municipality of Gómez Palacio, Durango. The experimental site is located at 25º46'56" N and 103º21'02" W at an altitude of 1,100 m above sea level. The soil has a clay texture, with a bulk density of 1.07 g cm^{-3}, an organic matter content of 1.5 % and a pH of 8.3.

Precipitation and air temperatures during crop development are shown in Figure 1. The accumulated precipitation during the cycle was 22.4 mm. Maximum temperatures ranged from 28.7 to 43.1 °C and minimum temperatures from 13.1 to 27 °C. The highest temperatures that exceeded the optimal growth range in sorghum (6 - 37.7 °C)(3) occurred between 41 and 52 d after sowing (DAS).

Figure 1: Maximum, minimum and average temperature and precipitation recorded during the experimental period (April 18 to August 10, 2018)



The effect of six cutting heights (10, 20, 30, 40, 50 and 60 cm from the soil surface) on forage yield, nutrient composition and nutrient yield of forage sorghum silage was evaluated. The preparation of the land consisted of a fallow, double harrowing and leveling with scraper. The sowing was carried out in moist soil on April 18, 2018 with a Gaspardo precision seeder (model SPLC-4F) using a sowing density of 12 kg ha^{-1} of seed of the Silo Miel variety (Agricenter Zevilla, Torreón, Coahuila). Four furrows per treatment of 0.8 m in length at a distance of 0.75 m were sown using a completely randomized block design with four repetitions. There was an average density of 195,000 plants ha^{-1}. The fertilization was carried out with 134 kg ha^{-1} of N and 43 kg ha^{-1} of P_2O_5. The total phosphorus was applied at sowing, while the N was fractionated, applying 40 % of the total dose at sowing and 60 % before the first supplemental irrigation; 48 DAS. At sowing, 8 kg ha^{-1} of K and 10 kg ha^{-1} of S were also applied and, before the first supplemental irrigation, 18 kg ha^{-1} of Ca and 12 kg ha^{-1} of Mg were applied. Yara Mila Star® and Yara Bela Nitromag® were used as fertilizer sources (Yara, Guadalajara, Jalisco). Four irrigations were applied including a pre-sowing irrigation and three supplemental irrigations at 48, 65 and 85 DAS. A furrow irrigation system was used. At 25 and 46 DAS, applications of chlorpyrifos ethyl (Lorsban 480 EM®, BASF Inc., Germany) were made at the rate of 0.75 L ha^{-1} for the control of fall armyworm (*Spodoptera frugiperda*). Subsequently, at 50 and 83 DAS, applications were made for the control of yellow sugarcane aphids (*Melanaphis sacchari*) using Imidacloprid + Betacyfluthrin (Muralla Max®, Bayer, Mexico) and Sulfoxaflor (Toretto Isoclast® Active, Corteva Agrosciences, Guadalajara) at a rate of 0.25 ml ha^{-1} and 100 ml ha^{-1}, respectively. Weed control was performed manually.

The harvest of the crop was carried out on August 10, 2018, at 105 DAS when the grain reached the milky-dough stage, accumulating 2,118 heat-hours. The two central furrows were used as a useful plot, removing 1 m from each end to exclude the edge effect. In total, six meters in length for each of the treatments (9.12 m^2) were harvested. Each useful plot was harvested considering the different cutting heights of each treatment (10, 20, 30, 40, 50 and 60 cm) based on the soil surface. Fresh forage of each useful plot was weighed to estimate the green forage yield. From the total plants cut per plot, 15 plants were randomly selected and ground to a theoretical particle size of 2 cm using a mill Model JF5. From the fresh ground forage of each plot, three random samples of 500 g each were taken and dried at 60 °C until constant weight in a forced air stove to determine the DM content. The DM yield was determined by multiplying the green-based forage yield per hectare by the DM content of the forage before silage.

To make the mini silos, the first three repetitions of the chopped fresh forage of each treatment were used. Glass jars with an airtight lid of 1 L capacity were used, where the chopped fresh forage was compacted to a density of 261 kg of DM m^{-3}(14) in each mini silo considering the content of DM at the harvest of each treatment. The estimation of the DM content to determine the density in the mini silos was made with the microwave oven and an average DM percentage of 29.67 ± 0.42 % was estimated. Compaction of the forage in each mini silo was carried out manually with a macho meat tenderizer (Metaltex 779-012). All mini silos were stored in the laboratory at ambient temperature for 90 d.

When opening the mini silos, the first 5 cm were discarded. Subsequently, in each mini silo a sample of 20 g of fresh silage was taken to which 200 ml of distilled-deionized water was added and it was mixed for 30 sec in a high-speed blender. The diluted sample was filtered through three layers of cheese gauze and the pH was measured in the liquid with a portable potentiometer (OHAUS Model ST2100, Parsippany, NJ, USA)[15]. From the remnant of the fresh silage, 400 g was taken and sent to a private commercial laboratory (GAQSA, Querétaro, Mexico) to be analyzed using near-infrared spectroscopy (NIR; Mod. 951, Foss Electric, Hillerod, Denmark). Each fresh silage sample was homogenized and dried in an airflow furnace at 66.7 °C until constant weight. Subsequently, the samples were crushed in a blender, and consecutively, in a mill using a 1 mm mesh. In these samples, the contents of crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin, *in vitro* digestibility of NDF at 30 h (NDFD-30h), TND, NFC, NEL and ashes were analyzed. The determination of nutritional values was based on prediction equations and databases generated by the "Cumberland Valley Analytical Services (CVAS)". The calibration of the equipment considers the following procedure: selection of the sample at random, taking of the spectra of the sample, selection of the spectra representing the samples, laboratory analysis of the selected sample using the reference methodology, comparison of the results of the reference methodology with their respective spectra, internal validation with the samples and carrying out the analysis by the reference methodology and validation of the calibration equation with the reference results of the internal validation samples. Once the calibration equation with the reference results of the internal validation was satisfactory, it was used for the analysis of all samples.

The yields of NDF, NDFD-30h, TDN and NEL were estimated considering the content of these nutrients in the silage and the dry forage yield per hectare of each treatment.

The analysis of the information was carried out with the statistical program SAS version 9.3 (SAS Institute Inc., Cary, NC. USA). The results were analyzed by ANOVA using a randomized block design, with six treatments, of four and three repetitions for the variables of forage yield and silage quality, respectively. When significant differences were found (P<0.05), Fisher's protected least significant difference test was applied to compare means between treatments at the same level of significance.

Plant height after applying the treatments and forage yields are shown in Table 1. As expected, the plant height at harvest was higher when a cutting height of 10 cm was used and lower when the forage was harvested at 60 cm. Yield results indicated that fresh and DM productions can decrease from a cutting height of 40 and 50 cm, respectively, from the soil surface. These reductions can be considerable up to 12 % when the cutting height reaches 60 cm compared to cutting heights between 10 and 40 cm. In this regard, other works have reported that the DM yield reduces as the cutting height increases, and that the losses in yield can range from 10 to 20 % when the cutting height is greater than 20 cm in forage sorghum(11,12).

Table 1: Plant height and yields of fresh forage and DM of forage sorghum, in response to harvest height

	Cutting height (cm)						
Concept	**10**	**20**	**30**	**40**	**50**	**60**	**LSD**
Plant height, m	3.4^{a}	3.3^{ab}	3.3^{ab}	3.3^{ab}	3.3^{ab}	3.2^{b}	0.2
Fresh forage yield, t ha^{-1}	63.6^{a}	62.8^{a}	61.9^{a}	60.2^{ab}	58.2^{ab}	54.5^{b}	5.8
DM yield, t ha^{-1}	18.7^{a}	18.5^{a}	18.1^{a}	17.8^{a}	17.3^{ab}	16.1^{b}	1.6

^{ab} Means with different superscript between rows are significantly different ($P<0.05$).

The nutritional value of sorghum silage altered as the cutting height increased (Table 2). The NFD content reduced from 74.1 % to 66.9 % when increasing the cutting height from 10 to 20 cm, respectively, but no significant reduction was observed from 20 cm to the cutting height of 60 cm. The lignin content reduced from 8.1 % to 6.4 % when the cutting height increased from 10 to 30 cm, but there were no significant changes from 30 cm to the cutting height of 60 cm.

Table 2: Nutrient content and yield of sorghum silage at different harvest heights

	Cutting height (cm)						
Variable	**10**	**20**	**30**	**40**	**50**	**60**	**LSD**
Nutrients (% of DM)							
DM (% of silage)	29.4	29.5	29.3	29.5	29.7	29.6	0.6
CP	6.4	6.5	6.1	7.2	6.3	6.4	1.4
NDF	74.1[a]	66.9[b]	66.2[b]	64.0[b]	63.0[b]	62.9[b]	5.6
ADF	52.1[a]	49.3[ab]	47.8[ab]	44.8[b]	43.6[b]	43.3[b]	6.0
Lignin	8.1[a]	7.7[a]	6.4[b]	6.9[b]	6.4[b]	6.5[b]	0.8
NDFD-30 h (% NDF)	27.4[d]	29.3[cd]	30.2[c]	34.2[b]	35.6[b]	38.6[a]	2.1
NFC	4.5[c]	9.1[bc]	11.9[abc]	15.9[ab]	18.4[a]	18.2[a]	8.0
TDN	45.9[b]	49.4[ab]	49.8[ab]	52.5[a]	53.3[a]	52.7[a]	5.1
NEL (Mcal kg^{-1} DM)	1.0[b]	1.1[ab]	1.1[ab]	1.2[a]	1.2[a]	1.2[a]	0.1
Ashes	13.7[a]	12.5[ab]	12.4[ab]	11.5[b]	11.1[b]	10.9[b]	1.8
Nutrient yield (t ha^{-1})							
NDF	13.9[a]	12.4[ab]	11.9[b]	11.4[bc]	10.9b[c]	10.2[c]	1.5
NDFD-30 h	3.8	3.6	3.6	3.9	3.9	3.9	0.7
TDN	8.6	9.1	9.1	9.3	9.1	8.5	1.1
NEL (Mcal ha^{-1})	18,659	20,094	19,808	20,548	20,371	18,684	2,448

DM= dry matter, CP= crude protein, NDF= neutral detergent fiber, ADF= acid detergent fiber, NDFD-30h= *in vitro* digestibility of NDF at 30 hours, NFC= non-fibrous carbohydrates, TDN= total digestible nutrients, NEL= net lactation energy.

[abcd] Means with different superscript between rows are significantly different (P<0.05).

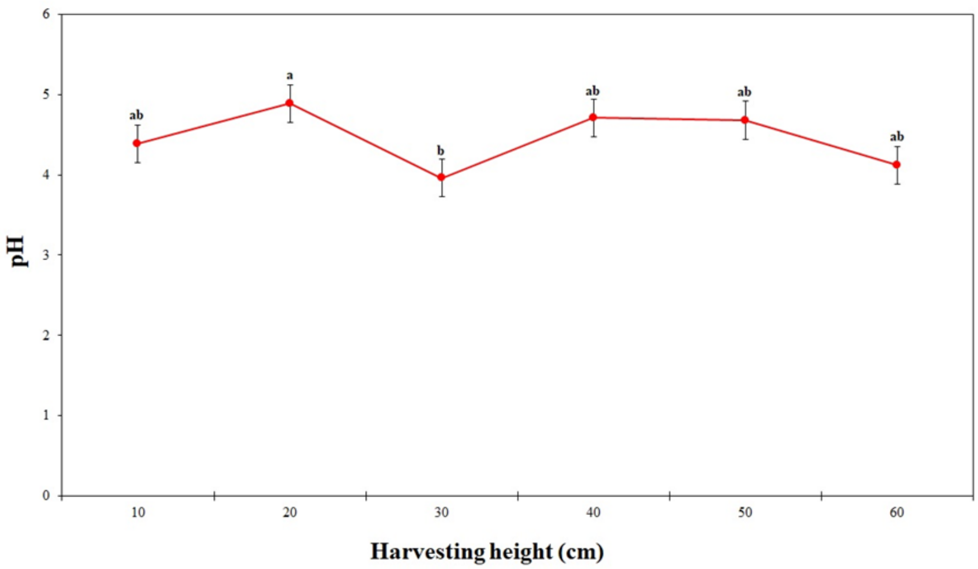
As a result of the observed changes in NDF and lignin contents, NDFD and the TDN concentration of the silage may increase after the forage was harvested at cutting heights of 40 and 20 cm, respectively. Similarly, the NFC content of sorghum silage increased as the cutting height increased, where the treatments of cutting height of 50 and 60 cm were the ones with the highest concentration of carbohydrates. This is probably associated with the lower lignification of the fiber and its greater digestibility, which in turn influenced the increase in the concentration of NEL of the silage from the cutting height of 40 cm(6,7).

The reduction in lignin content observed in the present study had a positive impact by improving fiber digestibility and energy availability in silage, which has been a strategy to improve the digestibility of fibrous forages(16). In a study where the cutting height was increased from 15 to 45 cm in the forage of Creole maize, black sorghum and King grass, the concentrations of lignin and NDF in maize and grass did not change; however, the highest cutting height reduced the concentration of NDF by 4.2 % and lignin by 1.3 % in sorghum forage(8). In another similar study, in forage maize, increasing cutting height from 12 to 45 cm at harvest reduced lignin content by 0.5 %, which contributed to the increase in fiber digestibility by 2.4 % in maize silage(9). It has been reported that for every percentage unit that NDFD increases in forage, DM consumption and milk production in cows increases by 0.17 and 0.25 kg d^{-1}, respectively(17).

Regarding nutrient production, it was found that the NDF yield decreased as the cutting height of forage at harvest increased (Table 2). This is due to the decrease in the concentration of NDF of silage and the increase in yield of DM of forage as the cutting height of the forage increases. However, the cutting height did not affect NDFD, TDN NEL NLE yields.

The pH of sorghum silage in response to the cutting height of the forage at harvest is shown in Figure 2. Cutting sorghum forage at a height of 30 cm from the base of the soil could favor better fermentation of silage, as a lower pH was observed (3.9). In contrast, silage of sorghum forage cut at a height of 20 cm registers the highest value (4.8). In relation to the other cutting heights, 10, 40, 50 and 60 cm were not statistically different, and cutting at 10 cm could lead to a pH in silage similar to harvesting forage at 30 cm. The final pH of silage can be affected by many factors, but it is mostly related to the concentration of carbohydrates in the forage(13). In the present study, the concentration of NFC in silage begins to increase after the forage was cut at 30 cm (Table 2), which coincides with the reduced pH of silage in this treatment. However, it is important to analyze, in future studies, other organic compounds and final products of fermentation that help confirm this effect. In forage maize, increasing the cutting height of the forage from 12 to 45 cm did not change the pH of the silage but increased the concentration of NFC such as starch(9).

Figure 2: pH of sorghum silage in response to cutting height in sorghum forage at harvest



Means with different letters are significantly different (P<0.05).

In conclusion, by cutting the sorghum forage between 20 and 40 cm from the soil surface, a silage with lower lignin content, greater fiber digestibility and good energy content was obtained, without compromising the yield of DM per hectare. In addition, harvesting the forage 30 cm from the base of the soil promotes a good fermentation of the silage. Therefore, increasing the cutting height of sorghum forage up to 40 cm above the soil basis improves the nutritional quality of silage without significantly reducing the DM yield.

Literature cited:

1. Jahanzad E, Jorat M, Moghadam H, Sadeghpour A, Chaichi MR, Dashtaki M. Response of a new and a commonly grown forage sorghum cultivar to limited irrigation and planting density. Agric Water Managen 2013;117:62-69. https://doi.org/10.1016/j.agwat.2012.11.001.

2. Peacock JM. Response and tolerance of sorghum to temperature stress. Sorghum in the Eighties. Proc Int Symp Sorghum, Patancheru, India 1982;1981:143-159.

3. Saberi AR, Siti AH, Halim RA, Zharah AR. Morphological responses of forage sorghums to salinity and irrigation frequency. African J Biotechnol 2011;10:9647-9656. DOI: 10.5897/AJB11.778.

4. Singh BR, Singh DP. Agronomic and physiological responses of sorghum, maize and pearl millet to irrigation. Field Crop Res 1995;42:57-67. https://doi.org/10.1016/0378-4290(95)00025-L.

5. Pedersen JF. Annual forages: New approaches for C-4 forages. In: Janick J. editor. Progress in new crops. ASHS Press, Alexandria, VA 1996;246-251.

6. Grant RJ, Haddad SG, Moore KJ, Pedersen JF. Brown midrib sorghum silage for midlactation dairy cows. J Dairy Sci 1995;78:1970-1980. https://doi.org/10.3168/jds.S0022-0302(95)76823-0.

7. Miron J, Zuckerman E, Adin G, Solomon R, Shoshani E, Nikbachat M, *et al*. Comparison of two forage sorghum varieties with corn and the effect of feeding their silages on eating behavior and lactation performance of dairy cows. Anim Feed Sci Technol 2007;139:23-39. https://doi.org/10.1016/j.anifeedsci.2007.01.011.

8. Elizondo-Salazar JA. Producción de biomasa y calidad nutricional de tres forrajes cosechados a dos alturas. Agron Mesoam 2017;28(2):329-340. doi 10.15517/ma.v28i2.23418.

9. Neylon JM, Kung Jr L. Effect of cutting height and maturity on the nutritive value of corn silage for lactating dairy cows. J Dairy Sci 2003;86:2163-2169. https://doi.org/10.3168/jds.S0022-0302(03)73806-5.

10. Gonzalez FC, Peña RA, Núñez HG, Jiménez GCA. Efecto de la densidad y altura de corte en el rendimiento y calidad del forraje de maíz. Rev Fitotec Mex 2005;28(4):393-397.

11. Creel RJ, Fribourg HA. Interaction between forage sorghum cultivars and defoliation managements. Agronomy J 1981;73(3):463-469. https://doi.org/10.2134/agronj1981.00021962007300030018x

12. Iptas S, Brohi AR. Effect of nitrogen rate and stubble height on dry matter yield, crude protein content and crude protein yield of a sorghum-sudangrass hybrid [*Sorghum bicolor* (L) Moench × *Sorghum sudanse* (Piper) Stapf.] in the three cutting systems. J Agron & Crop Sci 2003;189:227-232. https://doi.org/10.1046/j.1439-037X.2003.00001.x.

13. Kung Jr L, Moulder BM, Mulroney CM, Teller RS, Schmidt RJ. The effect of silage cutting height on the nutritive value of a normal corn silage hybrid compared with brown midrib corn silage fed to lactating cow. J Dairy Sci 2008;91:1451-1457. https://doi.org/10.3168/jds.2007-0236.

14. Sucu E, Kalkan H, Canbolat O, Filya I. Effects of ensiling density on nutritive value of maiz and sorghum silage. Rev Bras Zoo 2016;45(10):596-603. https://doi.org/10.1590/S1806-92902016001000003.

15. Contreras-Govea FE, Albrecht KA, Muck RE. Spring yield and silage characteristics of kura clover, winter wheat, and mixtures. Agron J 2006;98:781-787. https://doi.org/10.2134/agronj2005.0248.

16. Adesogan AT, Arriola KG, Jiang Y, Oyebade A, Paula EM, Pech-Cervantes AA, *et al*. Symposium review: Technologies for improving fiber utilization. J Dairy Sci 2019;102:5726-15334. https://doi.org/10.3168/jds.2018-15334.

17. Oba M, Allen MS. Evaluation of the importance of the digestibility of neutral detergent fiber from forage: effects on dry matter intake and milk yield of dairy cows. J Dairy Sci 1999;82:589-596. https://doi.org/10.3168/jds.S0022-0302(99)75271-9.