https://doi.org/10.22319/rmcp.v15i2.6554

Article

Dry matter accumulation, yield, and nutritional quality of forage of corn hybrids harvested at different days after sowing

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Abstract:

The objective was to evaluate the dry matter (DM) accumulation by component, yield, and nutritional composition of forage of four corn hybrids harvested at 121, 128, 135 and 142 d after sowing. In each harvest, five plants were randomly taken and separated into their components (stem, leaves, grain, cob, bracts, and tassel) and DM was determined; chemical composition and *in-situ* digestibility were analyzed in a composite sample of a whole plant. The accumulation of grain in the total DM increased from 35.8 to 43.9 % from 121 to 142 d to harvest, respectively, and diluted the other components, especially the proportion of stem and leaves, which decreased inversely proportional to the accumulation of grain. Total DM content differed between hybrids, from 3.8 and up to 8.3 percentage units on the same days to harvest. Nonetheless, the hybrid did not affect DM yield or grain production, increasing by 2.1 and 1.4 t ha^{-1} between harvests, respectively. NDF content decreased and starch increased (both linearly), affecting net energy for lactation, which increased from 1.49 to 1.56 Mcal kg^{-1} from 121 to 142 d to harvest, respectively. The interaction between days to harvest and hybrid affected starch content, which was 5.2 units higher in a hybrid with similar NFC and NDF content than its counterparts. DM, NDF and starch digestibilities were affected by the hybrid, but not by the days to harvest.

Keywords: Starch, Corn silage, Dairy cow.

Received: 12/09/2023

Accepted: 15/02/2024

Introduction

In northern and central Mexico, corn forage is widely used as silage in dairy cow diets[1], where it represents between 40 and 60 % of the dry basis of the diet[2]. The level of inclusion of corn silage in the ration is a function of the yield and nutrient quality of the forage[3]. In Mexico, in the last 10 yr, the yield per hectare of irrigated forage corn (fresh) has remained relatively unchanged[4]. This is mainly associated with inadequate selection of hybrids and early harvests[2,5], which reduces dry matter (DM) yield and grain content, which is where the highest energy value of forage is concentrated[6].

In central Mexico, the dairy basins of Aguascalientes and Altos-Norte de Jalisco share similar agroclimatic characteristics, contribute 9 and 19 % of national milk production, and cultivate around 15,000 and 45,000 ha of irrigated forage corn, respectively[4]. In this region, water scarcity, growing demand for corn silage and high costs of grains and concentrates make it necessary to make corn production more efficient per unit area and per m^3 of water used[2]. Therefore, increasing forage yield and quality is essential to achieve more sustainable milk production[1,2,7].

The use of outstanding hybrids is the first step to high yield and nutrient quality of forage[8]. Selecting the hybrid and harvesting it at an optimal stage of maturity is essential to achieve maximum accumulation of DM in the grain in a reasonable time[8,9]. Corn silage with better nutritional quality and locally produced can displace imported corn kernel from the diet and reduce feed costs. As the days to harvest are delayed, there is a greater accumulation of grain in the plant, increasing the energy value of the as the proportion of other components in the plant with less digestibility dissolve[9]. Nevertheless, increasing the number of days to harvest to favor grain accumulation decreases the digestibility of neutral detergent fiber (NDF), which negatively affects feed consumption in dairy cattle[6,9]. Thus, the hypothesis of the present study was that delaying the days to harvest increases the yield of DM and grain accumulation without affecting the digestibility of DM and NDF, which are mostly influenced by the hybrid effect. Therefore, the objective was to determine the response of four hybrids harvested at 121, 128, 135 or 142 d in DM accumulation by component, total DM yield, bromatological composition and digestibility of DM, NDF and starch.

Material and methods

Area of study and experimental design

The study was carried out under surface drip irrigation conditions in the SS-2019 cycle in a farm located in San Juan de los Lagos, Jalisco (21º17’40” N and 102º18’01” W) at 1,838 m asl; where the climate is semi-dry temperate with an average rainfall of 600 mm. The soil is alkaline (pH 7.8) with 1.9 % organic matter content and 71 mg kg^{-1} inorganic N. A randomized block design was used with an arrangement in split plots with four replications, where the large plot was the hybrid and the small plots the days to harvest. The hybrids used were DK-4018 (H1, Dekalb®), Noble (H2, Aspros®), Antílope (H3, Asgrow®) and XR-49 (H4, Ceres®), which were selected for having a yield above the average from a local assessment in the previous year. All hybrids were intermediate cycle and semi-toothed white grain. Harvesting was carried out at 121, 128, 135 and 142 d after sowing, which corresponded approximately to a grain maturity stage of approximately R2, R3, R4 and R5, respectively. The experimental plot consisted of four furrows 5.0 m long and 0.75 m wide, and the useful plot consisted of the two central furrows. Sowing was carried out on May 30 in moist soil, depositing the seed manually at a distance of 15 cm at the bottom of the furrow; the population density to harvest averaged 93,211 ± 2,090 plants ha^{-1}.

Agronomic management, data collection and sampling

Prior to sowing, between the first and second harrow pass, 4 t ha^{-1} of cattle compost and poultry manure with a concentration of 1.1 % N and 0.8 % P were applied; additionally, 200 kg of ammonium nitrate was applied between vegetative stages V3 and V6. The total N available in the soil for the crop was estimated at 340 kg ha^{-1}. There were no diseases and only one application for fall armyworm (*Spodoptera frugiperda*) in stage V3 was necessary, which was controlled with an application of chlorantraniliprole (Coragen, FMC®, Mobile, AL). Precipitation and minimum and maximum temperatures were recorded at a weather station (Em50, Meter Group Inc., Pullman, WA) located 80 m from the experimental site. Growing degree-days (GDDs) were calculated as the difference between the average temperature and the base temperature of corn (10 °C). Flowering was recorded when 50 % of the experimental plot exhibited male inflorescence (tassels releasing pollen) and female inflorescence (stigmas on young ears).

At 121, 128, 135 and 142 d after sowing (DAS), all the plants in the useful plot were harvested at 15 cm above ground level and the total fresh weight was recorded. A random sample of five whole plants was separated into five components: ears of corn, stem, leaves, tassel, and bracts. Each component was weighed fresh and placed in paper bags to dry at 55 °C to constant weight to determine DM. After drying, the ear of corn was separated into cob and grain, and samples of each component were ground (SR300 Retsch®, Staufen, Germany) to pass a 1 mm sieve; subsequently, a composite sample of 100 g (dry weight) of whole plant was made in proportion of each component to the total dry weight. The whole sample was used to perform bromatological and *in-situ* digestibility analyses.

Bromatological and digestibility analyses

Chemical analyses were carried out in the forage laboratory of Unión de Cooperativas de Consumo Alteñas S.C. de R.L. (UCCA, San Juan de los Lagos, Jal.). Ash content was determined by introducing 1.0 g of sample into a crucible and incinerating at 550 °C for 6 h in a muffle furnace. The content of NDF and ADF was determined sequentially in 0.5 g of sample introduced into a F-57 bag in the fiber analyzer (A200, Ankom Tech., Macedonia, NY); first, the determination of NDF was performed using alpha-amylase and sodium sulfite, followed by the determination of ADF in CTAB and H_2SO_4 solution. The total nitrogen (N) concentration was determined using the Dumas dry combustion procedure (Leco FP-528, St. Joseph, MO) and the crude protein (CP) content was calculated as % N × 6.25. The starch content was determined using the enzymatic-colorimetric procedure[10]. Initially, glucose was released by incubating 1.0 g of sample at 100 ºC for 1 h in 30 ml of 100 mM acetate buffer solution at pH 5.0 and 100 μL of alpha-amylase (Megazyme Ltd., Wicklow, Ireland) was added, then the reaction was incubated for 2 h at 50 ºC in 3 ml of GOPOD solution (Megazyme Ltd., Wicklow, Ireland) and then the absorbance was determined at 505 nm in a visible-light spectrophotometer (Genesys 10S, Thermo Sci., Madison, WI). Finally, the content of ethereal extract (EE) was analyzed with the gravimetric method in the Golfish equipment (Novatech GF-6, Tlaquepaque, Jal.) using hexane as a solvent.

Digestibility was determined *in situ* using two rumen-fistulated cows between 70 and 95 d in milk (ENLS, Zapotlanejo, Jal.) fed a fully mixed ration composed of 50 % corn silage, 25 % ground corn grain and 25 % protein-mineral core. First, 4.5 g of sample was placed in 10 × 20 cm dacron bags (R1020, Ankom Tech., Macedonia, NY) and they were secured with a strap. Duplicate samples were introduced into the ventral sac of the rumen to determine DM digestibility, NDF digestibility (NDFD) at 48 h, non-digestible fraction of NDF (uNDF) at 120 h, and starch digestibility at 12 and 24 h. All samples were removed simultaneously and rinsed in a 12 min cycle in a washing machine until clear water was obtained. Subsequently, the bags were dried at 55 ºC to constant weight to calculate the digestibility of the DM by initial *vs* final weight difference; NDFD, uNDF and starch digestibility were calculated by analyzing the bag residue with the procedures already described for NDF and starch.

Statistical analysis

All data were analyzed in the R statistical program (R Studio Inc., Boston, MA) using the *agricolae* package and the *aov* instruction for analysis of variance (ANOVA) with the following model:

$$Y = \mu + A_i + H_j + \delta_{ij} + D_k + (H \times D)_{jk} + E_{ijk}$$

Where:

Y is the response variable,

μ is the overall average,

A is the random effect of replication i (i= 1 to 4),

H is the fixed effect of the j-th hybrid (j= 1 to 4),

δ is the experimental error associated with the large plot (hybrid),

D is the fixed effect of the k-th day to harvest (k= 1 to 4),

(*D* × *H*) is the interaction between hybrid and days to harvest

E*ijk* is the residual error. For digestibility data, the random effect of the cow (l= 1 to 2) was included using the model described above.

All data are least squares means and statistical significance was stated at $P \leq 0.05$. Hybrid and day-to-harvest means, when a linear or quadratic effect was detected, were separated using Tukey's HSD test.

Results and discussion

Flowering, days to harvest, and GDD accumulation

The number of days to flowering was 73 for hybrids H1, H2 and H3 and 71 for hybrid H4. Days to harvest were September 29 (121 d), October 6 (128 d), October 13 (135 d) and October 20 (142 d); for each date, 1,266, 1,329, 1,397 and 1,470 GDDs accumulated, respectively. In the first 34 d of the crop, the mean temperature averaged 25 °C and then fluctuated between 19 and 23 °C.

DM accumulation by component

As shown in Table 1, the analysis of variance did not detect significant interactions between DAS and hybrid in five plant components, except for percentage of cob (P=0.01), where the differences were minimal. The components with the lowest proportion were tassel, cob, and bracts, which remained relatively similar in proportion in the four harvests and together accounted for about 14.5 % of the total DM. In contrast, the components with the highest proportion were stem, leaves, and grain, with the percentage of the latter increasing as the days to harvest progressed.

Table 1: Dry matter (DM) accumulation by plant component, DM content, and whole plant yield of four hybrids harvested at different days after sowing (DAS)

	Component, % of total DM						Whole plant	
	Stem	**Leaves**	**Tassel**	**Grain**	**Cob**	**Bracts**	**DM, %**	**DM, t/ha**
DAS[1]								
121	20.4[A]	28.3[A]	0.8	35.8[C]	6.7	8.0[A]	25.8[D]	24.9[C]
128	18.6[B]	26.2[B]	0.8	40.2[B]	6.6	7.6[B]	29.5[C]	25.7[C]
135	18.7[B]	25.6[B]	0.8	41.7[B]	6.4	6.8[BC]	34.6[B]	30.3[B]
142	19.3[B]	23.3[C]	0.6	43.8[A]	6.4	6.6[C]	37.8[A]	33.3[A]
Hybrid[2]								
H1	19.7[b]	25.8	0.7[b]	39.9[b]	6.2	7.7[a]	32.3[b]	29.0
H2	19.2[b]	26.7	0.6[b]	39.7[b]	7.0	6.8[b]	29.0[c]	28.1
H3	17.3[c]	25.3	0.7[b]	42.0[a]	6.7	8.0[a]	35.2[a]	28.9
H4	20.7[a]	25.6	1.0[a]	40.0[b]	6.1	6.6[b]	31.2[b]	28.3
SEM	0.354	0.451	0.025	0.481	0.074	0.163	0.885	0.791
DAS	Q**	L**	NS	Q*	NS	L**	L**	L**
Hybrid	< 0.01	0.184	< 0.01	< 0.01	NS	< 0.01	< 0.01	0.805
D × H	0.662	0.089	0.468	0.226	0.013	0.061	0.014	0.865

[1]Sowing date: May 30, 2019.

[2]Hybrid: (H1: DK-4018; H2: Noble; H3: Antílope; H4: XR-49).

SEM= standard error of the mean; DAS= response of linear (L) or quadratic (Q) days to harvest denoted by: *0.01 < *P*≤0.05 and **(*P*<0.01), D × H= interaction between DAS and hybrid, NS= not significant.

[ABC] Means with different uppercase literals differ in DAS (*P*≤0.05)

[abc] Means with different lowercase literals differ between hybrids (*P*≤0.05).

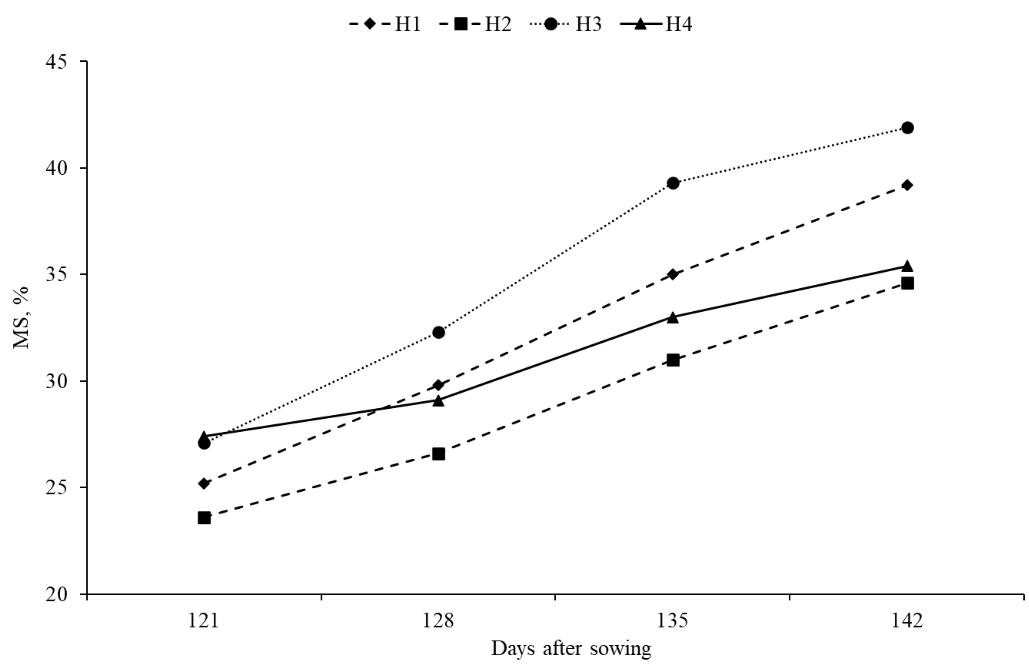
The percentage of stem showed a quadratic response (*P*<0.01), decreasing from 121 to 128 d to harvest and from which it remained without significant changes. In addition, it was observed that the hybrid affected the stem percentage (*P*<0.01), H4 surpassed H1, H2 and H3 by 1.1, 1.6 and 3.5 units, respectively. The percentage of leaves decreased linearly (*P*<0.01), decreasing 1.2 percentage units between harvests, but no hybrid effects were detected in this component. The percentage of grain increased quadratically (*P*=0.02) with the days to harvest, increasing by 4.5 percentage units from 121 to 128 d, and between 0.6 and 2.2 units from 135 and 142 d, respectively. Hybrid H3 outperformed hybrids H1, H2 and H4 in grain percentage by 2.1, 2.3 and 2.1 units, respectively. The largest increase in grain ratio from 121 to 128 corresponded to a decrease in stem percentage over the same period.

The proportion of tassel was not affected by the days to harvest, but differences between hybrids (*P*<0.01) were detected, which may not be important in the total composition of the plant due to its low proportion to the total DM. The percentage of cob was not affected by the days to harvest or hybrid and remained relatively constant, averaging 6.5 ± 0.3 % of the total DM. The proportion of bracts exhibited a linear response (*P*<0.01), decreasing at a rate of 0.3 percentage units between harvests; a difference was also detected between hybrids (*P*<0.01) and it was higher in H1 and H3 compared to hybrids H2 and H4 (7.7 and 8.1 *vs* 6.8 and 66 %, respectively). Hybrids H1 and H3, with the highest proportion of bracts, also had higher grain accumulation.

Whole plant DM content and yield

The interaction between hybrid and days to harvest affected DM content (*P*<0.01), as shown in Figure 1. Hybrids H3 and H2 had the highest and lowest DM content in the four harvests, respectively; on the other hand, hybrid H1 exhibited a DM accumulation almost linear and intermediate between H3 and H2. In contrast, hybrid H4 showed higher variation in DM accumulation between harvests. These discrepancies may be mostly associated with grain accumulation, but it could also be that the stay-green trait of each hybrid to conserve moisture (mainly in the stems) affects the DM content(11). The accumulation of DM increased linearly (*P*<0.01) at a rate of 3 weekly percentage units, equivalent to 0.4 % per day (Table 1). DM accumulation has been reported to be around 0.7 to 1.0 % per day under temperate conditions(12,13). In the present study, drip irrigation and the regular distribution of rainfall recorded in the cycle could have helped to keep soil moisture constant and reduce plant moisture loss.

Figure 1: Dry matter (DM, %) content in forage of four corn hybrids (H1=DK-4018, H2=Noble, H3=Antilope, and H4=XR-49) grown under irrigated conditions and harvested at 121, 128, 135 and 142 days after sowing



abcdfghi Means with different literals differ statistically (*P*≤ 0.05).

DM production increased linearly (P<0.01) at a rate of 2.1 t ha^{-1} per week, but there was no hybrid effect despite the interaction detected in DM accumulation. The increase in DM production was mainly due to grain accumulation as it was the only component that increased in proportion to the total DM with days to harvest. Grain production (t ha^{-1}) increased linearly with days to harvest (P<0.01) and was 8.9, 10.3, 12.6 and 14.6 t ha^{-1} at 121, 128, 135 and 142 d to harvest, respectively, but no hybrid effect or its interaction with days to harvest was detected.

Chemical composition

Except for CP and EE contents, the other bromatological variables were affected by the days to harvest and hybrid (Table 2). CP and EE contents remained within normal and relatively stable ranges, with significant differences between hybrids, but these were minimal. In contrast, the values of NDF, ADF, NFC and starch differed to a greater degree between days to harvest and between hybrids. NDF content decreased linearly (P<0.01) at a rate of 1.6 percentage units between harvests, while the proportion of ADF increased linearly (P<0.01) at a rate of 0.9 percentage units per week. Differences were also detected between hybrids for NDF and ADF contents (both P<0.01), where hybrids H3 and H4 accumulated lower percentages of NDF and ADF than H1 and H2 (Table 2). These findings differ from those reported in a local study in which NDF and ADF decreased by about 3.1 and 1.0 percentage units, respectively, over a 10-d period(14). In another study in which four harvests were carried out at similar DM content, a reduction in NDF and ADF was also reported; this was attributed to the dilution of these components due to the increase in grain percentage(9). In the present work, it is speculated that the low cut height (15 cm) at which the harvest was carried out may have caused more cellulose at the expense of hemi-cellulose; this has been documented in other studies in which a shorter stem accumulates more ADF and lignin(15,16).

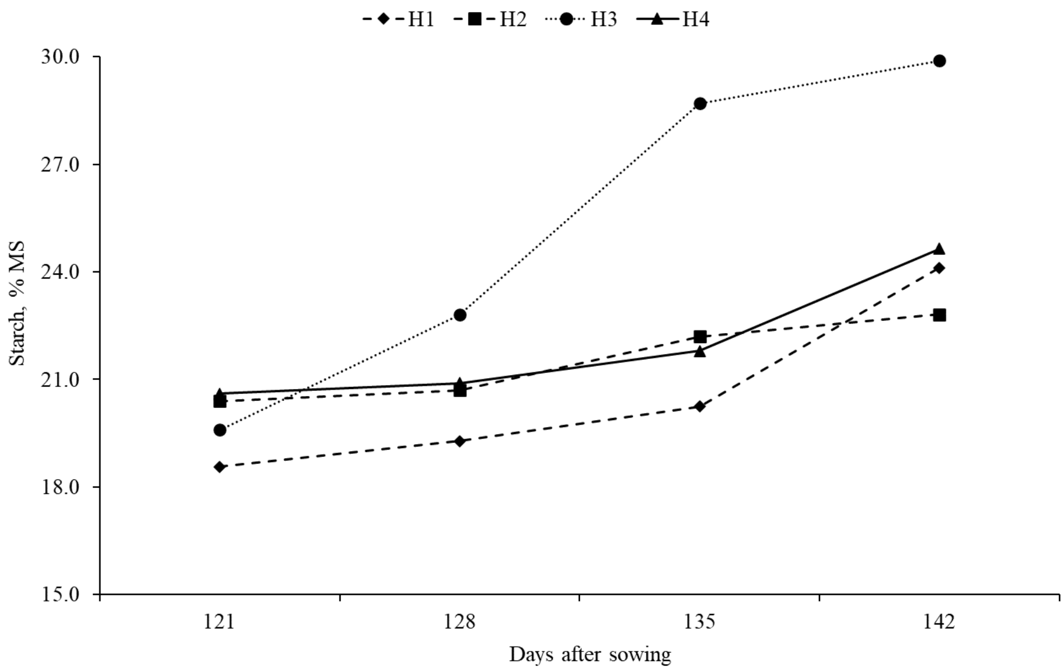
Table 2: Dry matter (DM) chemical composition in whole corn plant of four hybrids harvested at different days after sowing (DAS)

	% DM[1]							
	CP	**NDF**	**ADF**	**STA**	**NFC**	**EE**	**ASH**	**NEL Mcal kg^{-1}**
DAS[2]								
121	8.0	52.1^{A}	22.5^{D}	19.8^{D}	30.9^{D}	2.4	6.6^{A}	1.49^{D}
128	7.8	49.9^{B}	24.2^{C}	20.9^{C}	33.4^{C}	2.6	6.3^{A}	1.51^{C}
135	7.5	48.3^{C}	24.8^{B}	23.2^{B}	35.1^{B}	2.8	6.3^{A}	1.52^{B}
142	7.9	45.6^{D}	25.9^{A}	25.4^{A}	38.1^{A}	2.8	5.6^{B}	1.56^{A}
Hybrid[3]								
H1	7.6^{c}	49.5^{a}	25.1^{a}	20.6^{d}	33.6^{b}	2.8^{b}	6.5^{a}	1.51^{b}
H2	7.3^{d}	49.4^{a}	25.0^{a}	21.5^{c}	34.5^{ab}	2.2^{d}	6.6^{a}	1.50^{c}
H3	7.9^{b}	48.7^{b}	23.7^{b}	25.2^{a}	34.5^{a}	3.0^{a}	5.9^{b}	1.54^{a}
H4	8.5^{a}	48.2^{b}	23.7^{b}	22.0^{b}	34.7^{a}	2.7^{c}	5.9^{b}	1.53^{a}
SEM	0.020	0.246	0.062	0.034	0.286	0.022	0.064	0.006
DAS	NS	L**	L**	L**	L**	NS	Q*	L*
Hybrid	< 0.01	< 0.01	< 0.01	< 0.01	0.042	< 0.01	< 0.01	< 0.01
D × H	0.610	0.054	0.201	< 0.01	0.072	< 0.01	< 0.01	0.060

[1]Expressed as % of total dry matter (DM) of whole plant, unless otherwise indicated.
CP= crude protein, NDF= neutral detergent fiber, ADF= acid detergent fiber, STA= starch, NFC= non-fibrous carbohydrates, EE= ethereal extract, ASH= ashes; NEL= net energy for lactation calculated with the chemical composition presented here and digestibility of NDF at 48 h (Eq. 2.11; NRC, 2001).
[2]Sowing date: May 30, 2019.
[3]Hybrid: (H1= DK-4018; H2= Noble; H3= Antílope; H4= XR-49).
SEM= standard error of the mean; DAS= response of linear (L) or quadratic (Q) days to harvest denoted by: *0.01 < $P \leq 0.05$ and **($P<0.01$), D × H= interaction between DAS and hybrid, NS= not significant.
[ABC] Means with different uppercase literals differ in DAS ($P \leq 0.05$)
[abc] Means with different lowercase literals differ between hybrids ($P \leq 0.05$).

NFC content increased linearly ($P<0.01$) at a rate of 1.8 percentage units per week. The increase in NFC was inversely proportional to the decrease in NDF. Although there were differences in NFC between hybrids ($P<0.01$), these were minimal, from 0.9 to 1.1 %, and only hybrid H1 differed with the lowest NFC content. In the present study, the values obtained for NFC at 135 and/or 142 d to harvest were lower than those reported in other studies at similar days to harvest(9,14). Starch accumulation was affected by the interaction between days to harvest and hybrid ($P<0.01$); hybrid H3 consistently outperformed the other materials at 128, 135 and 142 d to harvest, except at 121 d to harvest, when starch content differed slightly between hybrids (Figure 2). This could be related to the variability observed in DM and grain accumulation, which affects starch synthesis in grain(17). Regarding days to harvest, a linear effect (*P*<0.01) was detected in starch accumulation, which increased at a rate of 1.4 units between harvests.

Figure 2: Starch content in the dry matter (DM) of forage of four corn hybrids (H1= DK-4018, H2= Noble, H3= Antílope, and H4= XR-49) grown under irrigated conditions and harvested at 121, 128, 135 and 142 days after sowing



abcdfg Means with different literals differ statistically ($P \leq 0.05$).

Digestibility

Table 3 shows the digestibility parameters evaluated at different incubation times *in situ*. No interactions between hybrid and days to harvest were detected for any of the parameters evaluated. Contrary to expectations, the days to harvest did not affect DM digestibility, NDF digestibility (NDFD) or starch digestibility. These findings differ from those reported in other studies in which NDFD at 36 or 48 h decreases by delaying the days to harvest and the maturity of the plant(14,18). On the other hand, the NDFD values reported here are lower than those reported in other local studies using the same *in-situ* method and incubation time(14,19). On the other hand, DM digestibility and NDFD were affected by the hybrid (*P*=0.02 and *P*=0.01, respectively). Hybrid H1, which had the highest DM digestibility, also obtained the superior NDFD. The increase in DMD is associated with grain accumulation, while the decrease is attributed to a lower NDFD(9,20). However, in the present study, the higher grain accumulation of hybrid H3 did not compensate for its lower NDF digestibility.

Table 3: *In-situ* digestibility of dry matter, neutral detergent fiber and starch of four corn hybrids harvested at different days after sowing (DAS)

	***In-situ* digestibility**				
	DMD_{48} % DM	**$NDFD_{48}$ % NDF**	**$uNDF_{120}$ % NDF**	**STD_{12} % starch**	**STD_{24} % starch**
DAS[1]					
121	59.6	32.2	47.3	46.9	96.7
128	59.0	30.1	47.6	47.0	95.6
135	60.2	30.2	48.8	46.6	94.5
142	60.7	30.0	49.3	44.6	94.4
Hybrid[2]					
H1	62.0[a]	34.2[a]	47.1	43.2[c]	96.9
H2	57.9[c]	30.5[ab]	49.6	48.6[a]	95.3
H3	60.0[b]	29.6[b]	49.2	46.8[b]	93.8
H4	59.5[b]	28.2[b]	48.2	46.5[b]	95.1
SEM	1.600	1.130	1.530	1.230	1.620
DAS	NS	NS	NS	NS	NS
Hybrid	0.021	0.041	0.257	0.014	0.265
D × H	0.140	0.072	0.128	0.124	0.202

[1]Sowing date: May 30, 2019.

[2]Hybrid: (H1: DK-4018; H2: Noble; H3: Antílope; H4: XR-49).

DMD_{48}= dry matter (DM) digestibility at 48 h of incubation, $NDFD_{48}$= neutral detergent fiber digestibility (NDF) at 48 h of incubation, $uNDF_{120}$= non-digestible NDF at 120 h of incubation, STD_{12}= starch digestibility at 12 h of incubation, STD_{24}= starch digestibility at 24 h of incubation.

SEM= standard error of the mean; DAS= linear (L) or quadratic (Q) effects of days to harvest denoted by: *0.01 < $P \leq 0.05$ and **($P<0.01$), D × H= interaction between DAS and hybrid.

[abc] Means with different literals differs ($P \leq 0.05$).

The fraction of non-digestible NDF (uNDF) at 120 h did not differ between days to harvest or between hybrids, and the means were 48.2 ± 0.9 and 48.2 ±1.4 %, respectively. In the present study, uNDF values were up to 10 units higher than those reported in other studies[(18,19)]. A high value of uNDF is associated with lignified fiber fractions, mainly from the base of the stem, where more lignin accumulates with plant senescence and increase in DM content[(19,20,21)]. Thus, it is possible that the low values of uNDF found in this study are associated with the low cut height used in the present study, compared to the aforementioned studies (15 *vs* 25 cm, respectively) and another local study using up to 40 cm of cut height[(22)]. Finally, starch digestibility at 12 or 24 h was not affected by the advance of days to harvest, and only a hybrid effect (*P*=0.01) was detected on starch digestibility at 12 h. Although all hybrids used were semi-toothed grains, it is possible that the vitreosity gradient at grain maturation affected starch digestibility at 12 h and this was without effect at 24 h[(23)].

Conclusions and implications

In the present study, grain accumulation and DM content increased by delaying the days to harvest and were influenced by the hybrid effect. Nonetheless, DM yield was not affected by the hybrid and only increased with days to harvest. The NDF content decreased and the starch content increased as the days to harvest progressed, but this factor did not affect the digestibility parameters evaluated. In general, DM yield and grain accumulation can be maximized by delaying harvest by up to 142 d without affecting NDF digestibility, but some agronomic strategies to harvest need to be explored to reduce the value of uNDF.

Acknowledgements

To CONAHCyT for the support granted to the first author to carry out his postgraduate studies. Thanks to Proteína Animal S.A. de C.V (PROAN), Unión de Cooperativas de Consumo Alteñas S.C. de R.L. (UCCA) and the National Institute of Forestry, Agricultural and Livestock Research (INIFAP, for its acronym in Spanish), who provided the financial, technical, and scientific means to carry out the study. Likewise, thanks are given to Escuela Nacional de Lechería Sustentable S.P.R. de R.L. (ENLS) for the care of the rumen-fistulated cows used in the digestibility study.

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