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Canola and Oat Forage Potential Evaluation in Four Early Planting Dates

Juan Isidro Sánchez-Duarte[1], David Guadalupe Reta-Sánchez[1,*], José Antonio Cueto-Wong[1], Arturo Reyes-González[1] and Esmeralda Ochoa-Martínez[1]

[1]Campo Experimental La Laguna, Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP). Blvd. José Santos Valdez 1200 Pte. Col. Centro, Matamoros, Coahuila, CP 27440, México.

[*]Corresponding Author: David Guadalupe Reta-Sánchez. Email: reta.david@inifap.gob.mx.

Abstract: Canola and oat forage potential may be affected by climatic conditions when sown early. The objective of this study was to evaluate the forage canola and oat potential in four early sowing dates (September 11 and 25; October 9 and 23) during the 2012-2013 and 2013-2014 cycles in Matamoros, Coahuila, Mexico. Growth cycle duration, chemical composition, dry matter (DM), crude protein (CP), and net energy for lactation (NE_L) yields were determined. High temperatures and long photoperiods affected crops seeded on September 11, accelerating growth and reducing canola (26.6%-31.7%) and oat (15.8%) DM yields. As of September 25, canola cv IMC 205 reached DM yields (7746 kg ha^{-1}-9276 kg ha^{-1}) similar to those obtained by oat (8115 kg ha^{-1}-9507 kg ha^{-1}), while canola cv Hyola 401 obtained such yields only until October 23. Canola chemical composition was better than that found in oat, with higher CP, but lower acid detergent fiber (ADF) and neutral detergent fiber (NDF) contents. Canola equaled oat CP yields (972 kg ha^{-1}-1215 kg ha^{-1}) in the first sowing date, while in the other three other canola sowings reached higher yields (1193 kg ha^{-1}-1889 kg ha^{-1}). As for NE_L yields, no difference was observed between both species. The best sowing date for canola is from September 25 on, with CP production advantages over oat.

Keywords: *Avena sativa* L.; *Brassica napus* L. var. oleifera; chemical composition; dry matter yield; nutrients

1 Introduction

Dairy cattle production is a major farming sector economic activity in the Comarca Lagunera, Mexico. Forage in these production systems is obtained through intensive crop farming under irrigation, yielding three harvests per year [1]. Main crop patterns with annual species established during the spring, summer, and autumn-winter cycles are corn-corn-oat and sorghum-sorghum-oat, respectively. However, low water availability and a limited number of available forage crops limit forage production in dairy systems in this region [2]. Therefore, to encourage sustainable and profitable future milk production, there is a need to identify forages of alternative species and production systems with more efficient water use.

In the Comarca Lagunera, Mexico, alternative forages that may contribute to improve forage productivity in dairy production systems, have been studied. The species offering better opportunities for improving forage productivity are those which showed outstanding results during the autumn-winter cycle, because they were more precocious, presented less evapotranspiration rates, and reflected higher crude protein content values [2-6]. Among such species, canola (*Brassica napus* L.) was one of the crops best adapting to traditional autumn-winter forage crop production systems [3], showing acceptable forage production and chemical composition [7,8].

Because of its origins, canola is a plant traditionally grown as an oilseed crop, although it is also capable of producing high-quality forage during the autumn-winter cycle. Canola forage DM yields per hectare have been obtained (7312 kg ha^{-1} to 10300 kg ha^{-1}) which are similar or slightly lower than those of oat (8226 kg ha^{-1} to 9980 kg ha^{-1}; [4,5,9]). In addition, previous studies consistently reported canola with a better forage chemical composition (CP = 159 g kg^{-1} to 240 g kg^{-1}, NDF = 357 g kg^{-1} to 466 g kg^{-1}), in comparison to oat forage (CP = 82 g kg^{-1} to 131 g kg^{-1}, NDF = 566 g kg^{-1} to 632 g kg^{-1}; [4,5,6,9]). Nevertheless, further technological development to improve crop handling is still required in order to achieve efficient forage canola production.

A major aspect to determine in canola crop farming is its agronomic performance when sown early (September and October), and also its potential productivity against oat, the latter being the main traditional autumn-winter crop in this area. In autumn-winter cycle early sowings, average maximum temperatures reach 27.2°C to 29.3°C, with more than 12 hours photoperiod; both factors accelerate canola growth cycle and reduce its DM yield [7]. The optimal growth and development temperature for canola is around 20°C [10,11], with the rate of development responding positively to long days in the interval 12 to 16 hours [11]. Canola seed production and seed components response to different sowing dates has been well documented [12-16]; however, findings of canola seed are not necessarily appropriated for canola forage because of differences in growth stage at harvest and dry matter partitioning. Therefore, the objective of this study was to evaluate canola and oat forage potential in four early sowing dates (September 11 and 25; October 9 and 23). The hypothesis of this study was that canola forage potential would be higher than oat in early sowings in the study region.

2 Materials and Methods

2.1 Study Site, Soil Preparation, and Fertilization

This study was conducted on clay soil, at La Laguna Experimental Station in the Instituto Nacional de Investigaciones Forestales, Agricolas y Pecuarias (INIFAP) located in Matamoros, Coahuila, Mexico (25° 32’ N, 103° 14’ W, and 1150 m above sea level). The soil in the experimental site is deep (> 1.8 m), with 150 mm m^{-1} available water [17], 0.75% organic C content, [1], and a pH value of 8.14. Climatic variables data were obtained from a meteorological station located 50 m away from the experiment site. Seedbed preparation was done through disk plough at a depth of 0.30 m, followed by double disking and zero-slope levelling.

Nitrogen and phosphorus fertilizer dose was calculated considering their availability in the soil and canola and oat extraction capacity, for an average DM yield of 8132 kg ha^{-1}, a 32.0 g kg^{-1} N concentration [4,5], and a 3.0 g kg^{-1} P content in the forage [18,19]. N and P estimated requirements were 260 kg N ha^{-1} and 62 kg P_2O_5 ha^{-1}, for both crops). Considering that the 0.3 m-deep soil analysis indicated an availability of 28.5 kg N ha^{-1}, and 24.8 kg P_2O_5 ha^{-1}, doses of 250 kg N and 60 kg P_2O_5 were applied per ha. Before sowing, each experimental plot was manually fertilized with 75 kg N ha^{-1} (ammonium sulphate) and 60 kg P_2O_5 ha^{-1} (monoammonium phosphate). Posteriorly, before the first and second irrigations, 87.5 kg N ha^{-1} were applied, in the form of granular ammonium sulphate. No potassium fertilizer application was made because soils in this area present high available potassium content, with average values of 3030 kg ha^{-1} at a depth of 0.30 m [1].

2.2 Treatments, Sowing, and Irrigation

Four sowing dates, two spring canola cultivars (*Brassica napus* L. var. oleifera), and one oat cultivar were evaluated in the 2012-2013 and 2013-2014 autumn-winter cycles. An experimental randomized complete block design with four replications and a split-split plot arrangement was used. Main plots corresponded to the production cycles, subplots to the sowing dates, and sub-subplots to the forage species. Sowing dates in both growth cycles were September 11, September 25, October 9, and October 23. The evaluated forage species were IMC 205 canola variety (Inter. Mountain Cargill), Hyola 401 canola hybrid (Interstate Seed Co.), and Cuauhtemoc oat cultivar (INIFAP).

All seeding was made by hand on dry soil. On the same sowing date, a 150 mm irrigation depth was applied. In order to favor seedling emergence, 60 mm irrigation was applied between 7 and 11 days after sowing (DAS). The experimental area was irrigated through a surface flood system using a 20.32 cm PVC multi-outlet gated pipes. Experimental plots were designed with twelve 6.0 m long rows, 0.20 m separated from each other. Measurements were taken from seven central 3.0 m long rows (4.2 m^2). As for seeding canola, 12 kg ha^{-1} was used (303000 to 355000 seeds kg^{-1}) with a germination varying from 80 to 90%. Plants were subsequently thinned to leave a 120 m^{-2} plant population density. Oat was sown at a seeding rate of 100 kg ha^{-1}.

Three irrigations of 120 mm were applied to meet the hydric requirements of oat and canola with different growth cycles. During the 2012-2013 cycle, these irrigations were made 28, 42, and 58 DAS in the first sowing date; 28, 44, 59 DAS in the second; 30, 57, and 75 in the third; and 43, 66, and 87 DAS in the fourth sowing-date. Regarding the 2013-2014 cycle, irrigations were made 28, 42, and 64 DAS in the first sowing date; 38, 66, and 91 DAS in the second; 36, 52 and 75 in the third; and 38, 66, and 91 DAS in the fourth sowing-date. Weeds were controlled by hand with a hoe.

2.3 Harvest, Forage Yield, and Chemical Composition

Crops were harvested when canola cultivars reached the end of their flowering stage (stage 4.4; [20]) and the oat was at ear half emerged stage. During the 2012-2013 cycle, IMC 205 canola cultivar was harvested 71, 76, 90, and 114 DAS in the first, second, third and fourth sowing dates, respectively, while Hyola 401 canola cultivar was harvested 67, 70, 79, and 105 DAS, in the same sowing-date order. In this first cycle and following the aforementioned sowing-date order, oat was harvested 71, 76, 90, and 105 DAS. During the 2013-2014 cycle, IMC 205 canola cultivar was harvested 75, 72, 97, and 105 DAS in the first, second, third, and fourth sowing dates, correspondingly. Hyola 401 canola cultivar was harvested 75, 72, 89, and 97 DAS, and oat 82, 99, 111 and 117 DAS, all in the same sowing-date order.

Fresh forage and DM yields were measured after harvest. DM content was determined from a 0.60 m^2 sample, randomly taken from the sample used for measurement purposes. For this purpose, three 1 m long central rows from each plot were sampled. The obtained plant samples were dried at 60°C in a forced-air oven until constant weight. DM yield was calculated by multiplying fresh forage yield by DM content of each plot.

Plants sampled to estimate DM content were also used to determine forage chemical composition (CP, NDF, ADF, and NE_L), which were ground in a Wiley® mill (Thomas Scientific, Swedesboro, NJ, USA) to pass through a 1 mm screen. Then, samples were analyzed according to the procedures described by [21] for NDF and ADF. Their N contents were analyzed according to the Kjeldahl method [22]. Net energy for lactation was estimated according to the procedures described by the National Research Council [23]. CP and NE_L yields per ha were calculated by multiplying nutrient plant content by the DM yield of each experimental plot.

2.4 Statistical Analysis

Based on the mentioned experimental design, a combined data analysis was performed. Analyses of variance ($p \leq 0.05$) were made for DM, CP, and NE_L yields, and for CP, ADF, NDF, and NE_L concentrations. To compare means, Fisher's protected least significant difference (LSD) test was used ($p \leq 0.05$). Also, a linear regression and/or quadratic analysis was performed ($p \leq 0.10$) in order to determine the relationship between the mean temperature and the crop growth cycle, as well as between the crop growth cycle and the forage DM yield. The obtained data were analysed through SAS statistical software [24].

3 Results

3.1 Climatic Conditions

Fig. 1 presents climatic conditions during crop cycle in both sudy years and the 30-years average (1985-2014). Mean temperature during 2012-2013 growht cycle was higher in November, December, and January than the mean temperature during 2013-2014 growth cycle and the 30-years average. Compared to the two growht cycles, 30-years mean temperature was only greater in September. Precipitation was the highest in September during the 2012-2013 growht cycle; however, precipitation from October to January was superior in 2013-2014 growht cycle compared to the earlier growht cycle and the 30-years average. No rainfall was observed during the two production cycles in February. In general, growth cycle major differences from one year to the other occurred in November, December, and January.

Specifically, during the 2012-2013 cycle sowing dates, temperatures above 20°C were observed for all species and varieties on September 11 and 25. As for the 2013-2014 cycle, average temperatures were above 20°C only on the first sowing date. Mean temperatures fluctuated between 14.9°C and 17.7°C on the October 9 and 23 sowing dates of the second cycle. Photoperiods at the beginning of each sowing date were 12.40 and 12.05 hours on September 11 and 25, respectivelly; while photoperiod was 11.72 hours on October 9, and 11.38 hours on October 23.

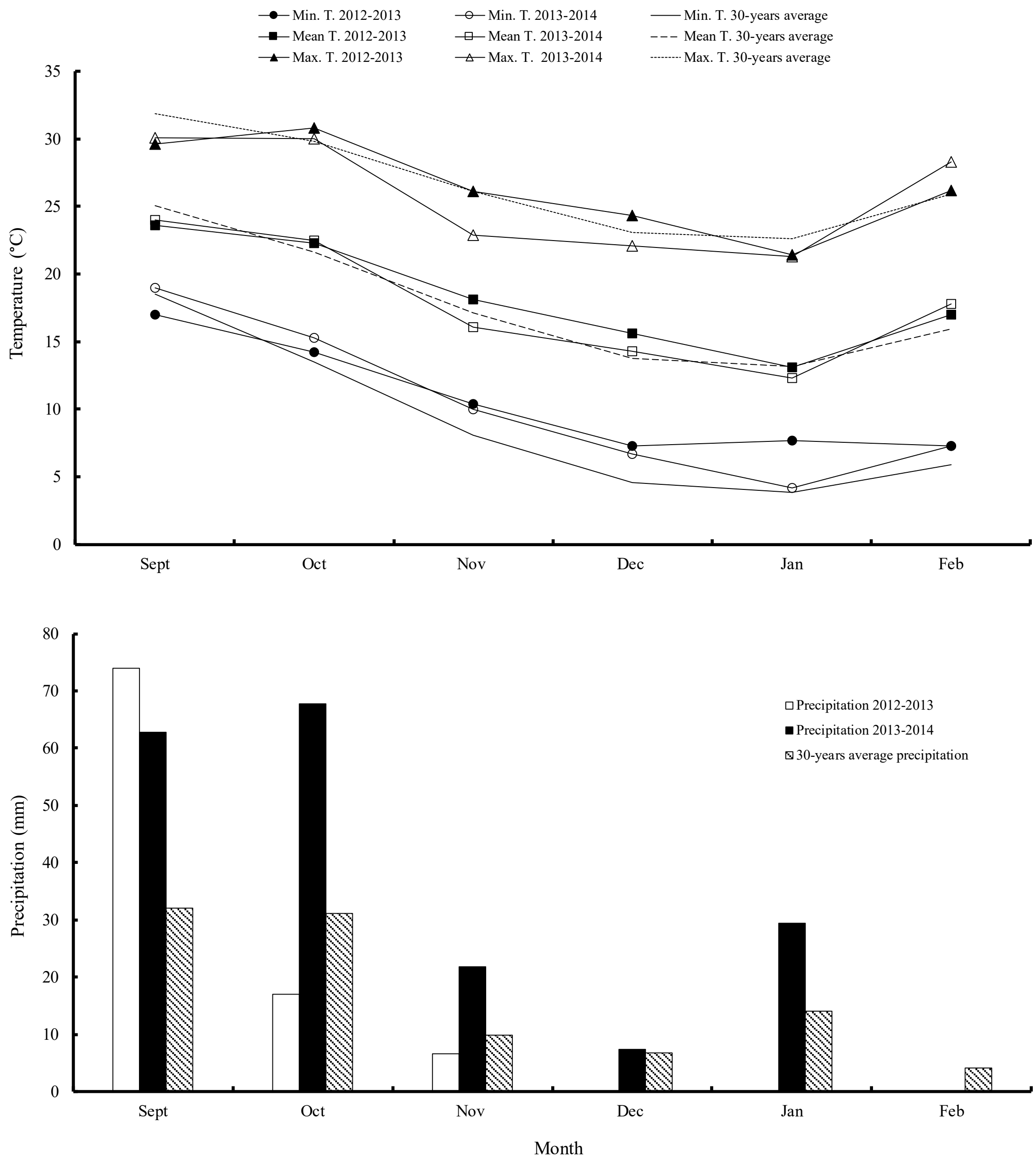

Figure 1: Climatic conditions during canola and oat development in four sowing dates in Matamoros, Coahuila, Mexico during the 2012-2012 and 2013-2014 growth cycles

3.2Analysis of Variance

Combined data analysis suggested significant interactions in most evaluated variables (Tab. 1). No significant differences were observed in the cycle × specie interactions for ADF and NE_L contents, sowing date × specie for NDF concentrations, and cycle × sowing date × specie for FDN contents and DM yield.

Table 1: Probability values from combined analysis of variance for oat and canola chemical composition and dry matter and nutrient yields in four sowing dates in Matamoros, Coahuila, Mexico during the 2012-2013 and 2013-2014 growth cycles

Variable†	C × SD‡	C × S	SD × S	C × SD × S
CP (g kg^{-1})	0.0121	0.0001	0.0145	0.0111
NDF (g kg^{-1})	0.0042	0.0073	0.1402	0.1488
ADF (g kg^{-1})	0.0060	0.1012	0.0093	0.0053
NE_L (MJ kg^{-1} MS)	0.0060	0.1015	0.0093	0.0053
DMY (kg ha^{-1})	0.0001	0.0249	0.0001	0.4818
CPY (kg ha^{-1})	0.0160	0.0007	0.0001	0.0095
NE_LY (MJ ha^{-1})	0.0001	0.0365	0.0001	0.0277

†CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; NE_L: net energy for lactation; DMY: dry matter yield; CPY: CP yield; NE_LY: NE_L yield.

‡($p \leq 0.05$) Interactions: C × SD = cycle × sowing date; C × S = cycle × specie; SD × S = sowing date × specie; C × SD × S = cycle × sowing date × specie.

3.3 Growth Cycle

When the assessed sowing dates were delayed between September 11 and October 23, the growth cycle was longer for both species. During the 2012-2013 cycle, oat, and canola IMC 205 and Hyola 401 growing cycle extended by 34, 43, and 38 days, respectivelly (Fig. 2(a)). In 2013-2014 such prolongation was 35 days for oat, 30 days for canola IMC 205 and 25 days for canola Hyola 401 (Fig. 2(b)).

Even though the oat growth cycle extended when the sowing date was delayed in the 2012-2013 cycle, its DM yield was not significantly affected (Fig. 3(a); b = 0.5284); whereas oat DM yield tended to increase quadratically as its growing cycle increased in the 2013-2014 cycle (Fig. 3(b); b = 0.1556; c^2 = 0.1600). Canola DM yield reflected a linear increase as both cultivars growth cycle extended during the 2012-2013 cycle (Fig. 3(a); b = 0.0873 to 0.1013). In the 2013-2014 cycle, the DM yield of canola IMC 205 was adjusted to a quadratic function (Fig. 3(b); b = 0.0713; c^2 = 0.0761). In the case of canola Hyola 401, its growth cycle prolongation did not significantly affect its DM yield (Fig. 3(b); b = 0.2972).

3.4 Forage Chemical Composition

Tab. 2 shows oat and canola forage chemical composition in four sowing dates, during both growth cycles. The concentration of CP in both forages was significantly affected by the interactions cycle × sowing date, cycle × specie, sowing date × specie, and cycle × sowing date × specie ($p \leq 0.05$). The content of NDF was affected by the interactions cycle × sowing date and cycle × specie ($p \leq 0.01$). Also, the interactions between cycle × sowing date, sowing date × specie, and cycle × sowing date × specie ($p \leq 0.01$) were different for ADF and NE_L contents.

Sowing dates did not modify oat and canola forage NDF, ADF or NE_L contents (Tab. 2; $p > 0.05$). Nevertheless, protein content in both canola cultivars differed from one sowing date to the other in the first growth cycle ($p \leq 0.05$), indicating that CP decreases in the cultivar Hyola 401 for the October 23 sowing date and in the cultivar IMC 205 for the September 25 and October 23 sowing dates (Tab. 2).

Canola presented a higher CP content, lower NDF and ADF values, and higher NE_L concentration than oat ($p \leq 0.05$) in both evaluation cycles. As for the NE_L variable, a variation among sowing dates was observed, in which canola IMC 205 showed NE_L values similar to those of oat in both evaluation cycles

($p > 0.05$). Comparison between canola cultivars suggested no differences between them regarding CP and NDF contents in all sowing dates ($p > 0.05$). Findings showed only an increase of ADF ($p \leq 0.05$) and a decrease of NE_L ($p \leq 0.05$) in canola IMC 205 on the October 23 sowing date (Tab. 2).

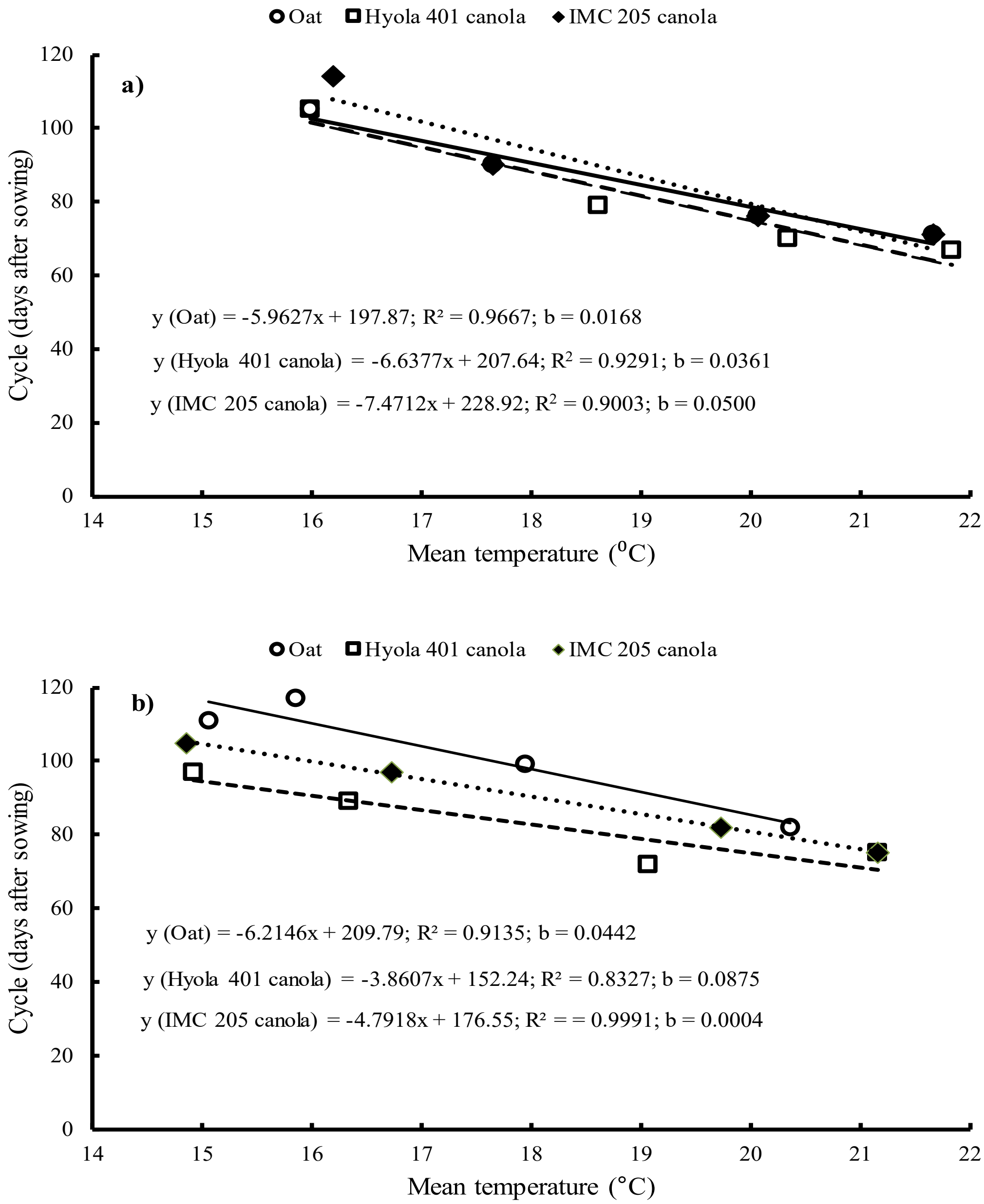

Figure 2: Relationship between mean temperature and growth cycle for canola and oat in four sowing dates in Matamoros, Coahuila, Mexico during 2012-2013 (a) and 2013-2014 (b) growth cycles. b = linear parameter of equation

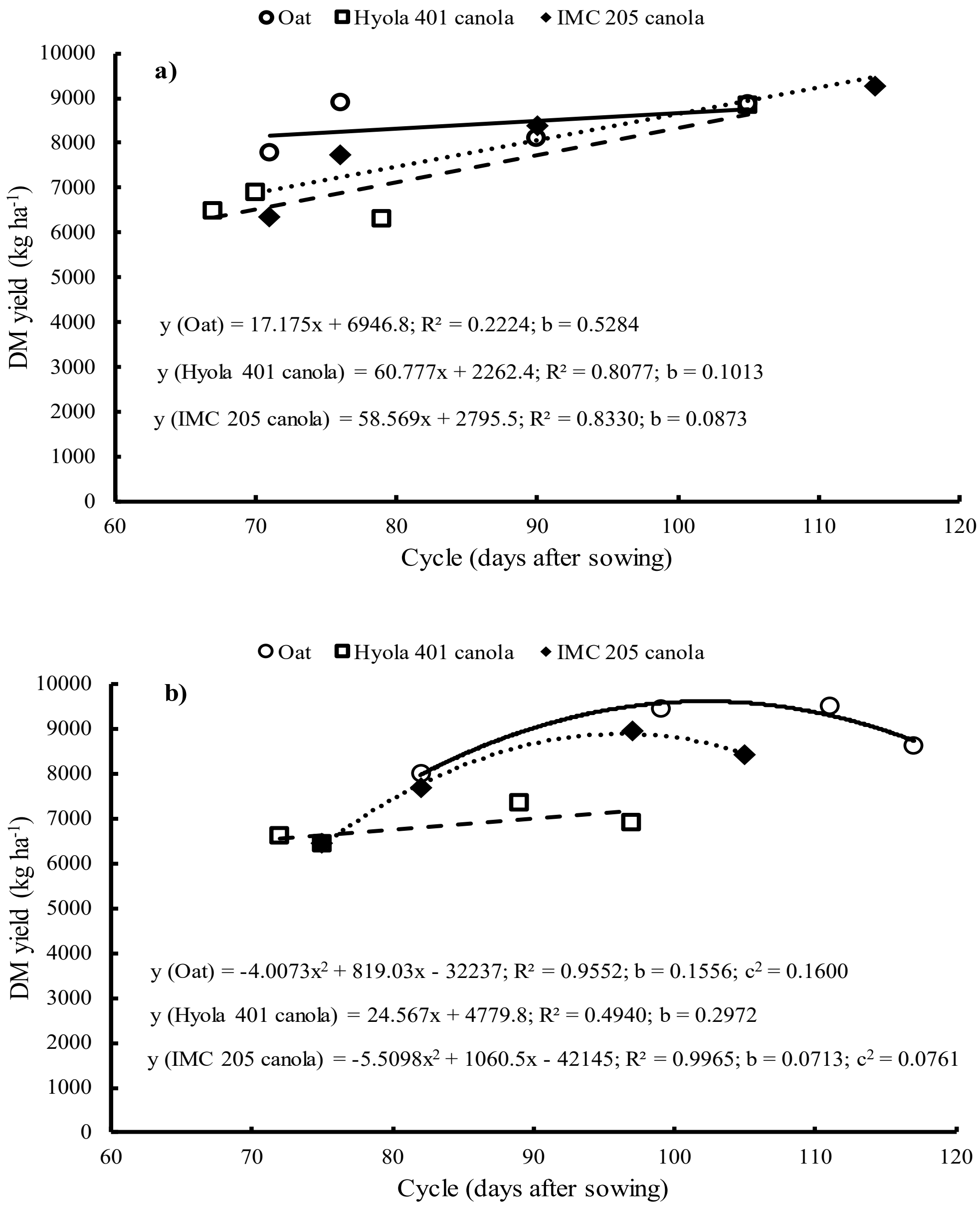

Figure 3: Relationship between growth cycle and dry matter (DM) yield for canola and oat in four sowing dates in Matamoros, Coahuila, Mexico during 2012-2013 (a) and 2013-2014 (b) growth cycles. b = linear parameter of equation; c^2 = quadratic parameter of the equation

Table 2: Forage chemical composition of canola cultivars and oat established in four sowing dates in Matamoros, Coahuila, Mexico during the 2012-2013 and 2013-2014 growth cycles

Sowing date/specie	CP[¶] (g kg^{-1})		NDF (g kg^{-1})		ADF (g kg^{-1})		NE$_L$ (MJ kg^{-1} DM)	
	2012-2013	2013-2014	2012-2013	2013-2014	2012-2013	2013-2014	2012-2013	2013-2014
Sept 11								
Oat	140.8	121.3	566.0	579.3	379.4	410.1	5.47	5.13
CnH401	197.4	207.1	349.6	417.7	315.6	339.0	6.17	5.91
CnIMC205	188.1	186.7	400.1	455.5	330.8	370.4	6.00	5.56
Sept 25								
Oat	128.6	124.2	576.7	613.9	386.4	420.5	5.39	5.01
CnH401	205.4	206.6	370.4	422.8	306.4	344.9	6.27	5.84
CnIMC205	166.2	211.5	409.5	450.6	335.6	363.2	5.95	5.64
Oct 9								
Oat	138.8	109.2	554.8	597.4	368.6	385.7	5.58	5.40
CnH401	220.4	223.2	337.7	439.4	292.2	355.4	6.42	5.73
CnIMC205	214.5	211.2	374.5	460.9	309.4	372.7	6.23	5.54
Oct 23								
Oat	136.6	113.6	529.5	624.1	343.8	418.3	5.86	5.04
CnH401	186.3	196.9	345.5	443.7	275.6	341.9	6.60	5.88
CnIMC205	168.1	209.6	418.1	445.0	351.1	348.4	5.78	5.81
LSD 0.05 [†]	27.3		69.2		47.3		0.52	
LSD 0.05 [‡]	28.9		77.4		54.2		0.60	
LSD 0.05 [§]	30.4		74.8		56.3		0.62	

[†]LSD (0.05) for sowing date (SD) subplot means in the same main plot (cycle) and sub subplot (specie); [‡] LSD (0.05) for sub subplot means in the same combination of main plot and subplot; [§] LSD (0.05) for main plot means in the same combination of subplot and sub subplot. [¶] CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; NE$_L$: net energy for lactation.

3.5 Dry Matter and Nutrient Yields

Yields of DM, CP and NE$_L$ were significantly affected by the interactions cycle × sowing date, cycle × specie, sowing date × specie, and cycle × sowing date × species (Tab. 3; $p \leq 0.05$). According to the comparison between growth cycles for the same specie and sowing date, for the October 23 sowing date, only the yields of DM and NE$_L$ in canola Hyola 401 were different, with higher yields in the 2012-2013 cycle ($p \leq 0.05$). No significant differences were observed in oat or in canola IMC 205 (Tab. 3; $p > 0.05$).

Comparison between species in the same growth cycle and sowing date reflected significant differences for DM and nutrients yields (Tab. 3; $p \leq 0.05$). In both growth cycles, yield differences among species were significant for the September 25, October 9, and October 23 sowing dates. In the 2012-2013 cycle and September 11 sowing date, DM yield was similar among species and varieties ($p > 0.05$) (Tab. 3). For the September 25 sowing date, canola IMC 205 reached DM yields statistically similar to the observed for oat ($p > 0.05$), while canola Hyola 401 only reached such results until the October 23 sowing date ($p > 0.05$). In the 2013-2014 growth cycle, oat produced a higher DM yield than those observed for both canola cultivars ($p \leq 0.05$) in the September 11 and 25 sowing dates. The canola cultivar Hyola 401 obtained lower DM yield than oat ($p \leq 0.05$) in all sowing dates, while the cultivar of canola IMC 205 produced similar DM yields to those of oat ($p > 0.05$) in the October 9 and 23 sowing dates.

Table 3: Dry matter and nutrient yields for canola cultivars and oat established in four sowing dates in Matamoros, Coahuila, Mexico during the 2012-2013 and 2013-2014 growth cycles

	DMY¶ (kg ha^{-1})		CPY (kg ha^{-1})		NE_LY (MJ ha^{-1})	
Sowing date/specie	2012-2013	2013-2014	2012-2013	2013-2014	2012-2013	2013-2014
Sept 11						
Oat	7781	8003	1095	972	42518	41002
CnH401	6497	6424	1285	1331	40079	37982
CnIMC205	6338	6436	1193	1199	38023	35841
Sept 25						
Oat	8899	9454	1142	1174	47873	47404
CnH401	6901	6597	1429	1363	43254	38571
CnIMC205	7746	7691	1284	1627	45969	43351
Oct 9						
Oat	8115	9507	1132	1078	45294	47837
CnH401	6309	7361	1386	1641	40496	42120
CnIMC205	8380	8945	1800	1889	52199	49472
Oct 23						
Oat	8866	8620	1215	941	51998	46501
CnH401	8852	6918	1645	1361	58478	40617
CnIMC205	9276	8426	1559	1770	53663	48860
LSD 0.05 †	1371		334		9243	
LSD 0.05 ‡	1573		360		10655	
LSD 0.05 §	1785		417		11301	

† LSD (0.05) for sowing date (SD) subplot means in the same main plot (cycle) and sub subplot (species); ‡ LSD (0.05) for sub subplot means in the same combination of main plot and subplot; § LSD (0.05) for main plot means in the same combination of subplot and sub subplot. ¶ DMY: dry matter yield; CPY: crude protein yield; NE_LY: net energy for lactation yield.

For the 2012-2013 growth cycle, CP yield was similar among species in the September 11 and 25 sowing dates ($p > 0.05$), whereas in the October 9 and 23 sowings, canola produced CP yields similar to ($p > 0.05$) or higher than ($p \leq 0.05$) those of oat (Tab. 3). In the October 9 sowing date, only the canola IMC 205 cultivar produced higher CP yields than those of oat ($p \leq 0.05$), while in the October 23 sowing date, the canola cultivar Hyola 401 surpassed the CP yield of oat ($p \leq 0.05$). For the 2013-2014 cycle, no significant difference was observed among species in regard to CP yield in the September 11 sowing date ($p > 0.05$). In the other three sowing dates, the CP yield of canola was equal to ($p > 0.05$) or higher than ($p \leq 0.05$) that reached by oat. In the September 25 sowing date, only canola IMC 205 surpassed the CP yield obtained by oat ($p \leq 0.05$), whereas in the October 9 and 23 sowing dates, both canola cultivars exceeded oat CP yields (Tab. 3; $p \leq 0.05$). A small variation was observed in NE_L yield among species; only a significant difference was found in the October 9 sowing date, which suggested that canola IMC 205 produced a higher NE_L yield than canola Hyola 401 ($p \leq 0.05$), but similar ($p > 0.05$) to that of oat (Tab. 3).

Significant differences were observed among all species and varieties and both growth cycles when comparing DM and nutrient yields in the sowing dates and growth cycle (Tab. 3; $p \leq 0.05$). Oat showed significant differences in DM yield only in the 2013-2014 cycle, while differences in NE_L yield were observed for the 2012-2013 cycle. Regarding oat CP yields, no differences were detected in any of the two cycles. In the 2013-2014 cycle, oat produced the highest DM yields ($p \leq 0.05$) in the September 25 and October 9 and 23 sowing dates, but no significant differences were detected among them ($p > 0.05$).

The lowest yield was obtained in September 11 ($p \leq 0.05$), which was only statistically similar ($p > 0.05$) to that of the October 23 sowing date. As for oat NE_L yield, the highest yields ($p \leq 0.05$) during the 2012-2013 cycle were obtained in the October 23 sowing date, which presented yields statistically similar ($p > 0.05$) to those in the September 25 and October 9 dates, and higher ($p \leq 0.05$) than the yield in the September 11 sowing date (Tab. 3).

DM and nutrient yields in both canola cultivars were affected by sowing dates (Tab. 3; $P \leq 0.05$). Canola IMC 205 reached the highest DM, CP and NE_L yields in the September 25, October 9 and October 23 sowing dates during both growth cycles ($p \leq 0.05$), although this cultivar showed lower DM and CP values in the September 25 sowing date as compared to those in the October 23 sowing in the 2012-2013 growth cycle ($p \leq 0.05$). Canola Hyola 401 significantly increased DM, CP, and NE_L yields in the October 23 sowing date, only during the 2012-2013 growth cycle ($p \leq 0.05$).

4 Discussion

4.1 Growth Cycle

Oat and canola growth cycle extended in accordance with sowing date delay, responding to a lower mean ambient temperature (from 21.83°C to 14.85°C; Figs. 2(a) and 2(b)) and to a shorter photoperiod, from 12.40 to 11.38 hours. At the beginning of the October sowings cycle, under 12.00-h photoperiods delayed oat and canola floral differentiation, while lower temperatures retarded their vegetative development [11,25,26].

Other studies previously reported changes in growth cycle duration as a response to temperature and photoperiod variations. For canola grown under controlled environmental conditions, it was found that a temperature increase from 13.5°C to 20.0°C reduced canola growth cycle to end of flowering (stage 4.4; [20]) by 12 days [27]. Furthermore, along with a difference of 3.4°C in temperature and 31 minutes in daylight length between sowing dates, a 12-day growth cycle reduction to flowering has been observed in canola sown in a field experiment [28]. In oat harvested at ear emergence was observed a 24-day growth cycle reduction when day/night temperature shifted from 13/13°C to 23/13°C [29].

4.2 Forage Chemical Composition

Differences in mean temperatures (14.85°C to 21.83°C) among sowing dates during oat and canola growth cycle, did not affect their values of NDF, ADF, or NE_L contents ($p > 0.05$). However, a CP decrease ($p \leq 0.05$) was observed in the last sowing date of both canola cultivars; although this response possibly was not a consequence of ambient temperature changes during the study period, but an effect of N content dilution due to a DM yield increase (Tab. 3), which has also been found in ryegrass and summer grass species [30,31].

Other experiments performed on canola have reported results differing from those observed in this study. An increase in ambient temperature may result in a decrease of CP and EN_L contents and an increase of NDF and ADF concentrations in forage [7,32]. In this sense, it has been suggested that an increase in forage fiber is positively related to an increase in cell wall lignificaton, which is an effect of high temperatures during the growth cycle [33]. Another study reported that forage from oat sown in autumn, with colder temperatures and shorter days, presented a higher nutritional value (NDF = 554 g kg^{-1}, ADF = 313 g kg^{-1} and in vitro NDF digestibility = 755 g kg^{-1}) than other oat sown and cultivated during the summer (NDF = 573 g kg^{-1}, ADF = 340 g kg^{-1} and in vitro NDF digestibility = 641 g kg^{-1}) [34].

According to this study, the better canola forage chemical composition results ($p \leq 0.05$), when compared to oat forage, were similar to those reported by previous studies carried out in the study area, where canola forage showed better CP concentration intervals (159.3 g kg^{-1} to 240.3 g kg^{-1}), but lower values of NDF (357.3 g kg^{-1} to 466.0 g kg^{-1}) and ADF (292.0 g kg^{-1} to 355.0 g kg^{-1}) contents when compared to oat forage (CP = 99.0 g kg^{-1} to 134 g kg^{-1}, NDF = 565.9 g kg^{-1} to 687.4 g kg^{-1} and ADF = 356.8 g kg^{-1} to 392.0 g kg^{-1}). Nevertheless, NE_L concentrations were statistically similar in both species, reaching values of 5.40 MJ kg^{-1} to 6.03 MJ kg^{-1} DM in oat, and 5.69 MJ kg^{-1} to 6.11 MJ kg^{-1} DM in canola [3,4,5,6,9].

4.3. Dry Matter and Nutrient Yields

Dry matter and nutrient yields comparison between growth cycles for the same combination of sowing dates and species showed that these variables were similar between oat and canola cycles ($p >$ 0.05), except for canola Hyola 401, which presented higher yields ($p \leq 0.05$) in the October 23 sowing date during the 2012-2013 growth cycle (8852 kg ha^{-1}). The DM and NE_L yields decreased in canola Hyola 401 during the 2013-2014 cycle ($p \leq 0.05$), as a consequence of low temperatures, which did not have the same effect on canola IMC 205 and oat. The average monthly minimum temperatures that affected crop growth fluctuated from 4.2°C to 6.7°C, which were lower values than those occurring during the 2012-2013 growth cycle (4.7°C to 7.3°C).

Since the optimum temperature to get the best oat growth and yield is 13°C to 19°C [25], this crop presented scant variation to mean temperature changes (14.85°C to 21.83°C) as an effect of the evaluated sowing dates. One significant DM and NE_L reduction did occur ($p \leq 0.05$) only in the September 11 sowing date, when ambient temperature reached mean temperature values of 21.83°C and a maximum temperature of 29°C. In such sowing date, high temperatures along with long photoperiods (> 12 hours) accelerated oat development, negatively affecting its yield potential [25,35].

Canola DM and nutrient yields reflected a higher variation than oat as an effect of the sowing dates, with differences according to each cultivar and growth cycle. Canola IMC 205 showed greater stability to temperature changes due to the sowing date, as it showed the highest DM and nutrient yields ($p \leq 0.05$) as of the September 25 sowing date, maintaining such production level until the October 23 sowing date. In a similar manner to oat, high temperatures in the September 11 sowing date significantly reduced DM and nutrient yields in canola IMC 205.

The cultivar of canola Hyola 401 maintained low DM and nutrient yields in the September 11, September 25 and October 9 sowing dates, increasing them later only in the October 23 sowing during the 2012-2013 cycle. Ambient temperature decreased on this last sowing date, reaching maximum temperatures of 21.4°C to 28.3°C and mean temperatures of 12.3°C to 18.1°C, which were close to the optimum temperatures reported for canola (20.0°C to 22.0°C; [10,11,26]. In contrast to the 2012-2013 cycle results, the DM and nutrient yields of canola Hyola 401 did not increase in the October 23 sowing date of the 2013-2014 cycle, possibly due to the effect of minimum temperatures (4.2°C to 6.7°C), which were lower than those registered for the 2012-2013 cycle (4.7°C to 7.3°C), affecting the growth and development of canola Hyola 401 to a greater extent.

The effect of high temperatures and long photoperiods on oat and canola growth cycles is frequently associated to a DM yield reduction in canola [7] and oat [35]. Both species presented such response in the September 11 sowing date, but reflecting variation according to each growth cycle and cultivar. DM yield decreased during the 2012-2013 cycle only in both canola cultivars (Fig. 3(a)); while in the 2013-2014 cycle, DM yield reduction was observed in both species, canola IMC 205 and in oat (Fig. 3(b)).

Dry matter yield reduction in canola as an effect of its growth cycle decrease has also been reported in another study [7]. The aim of this study was to evaluate canola forage potential growth established by different sowing methods during two growth cycles (2008-2009 and 2009-2010) and concluded that a higher DM yield was achieved in the second growth cycle. Maximum temperatures recorded during the mentioned last cycle (19.5°C to 25.6°C) were close to the optimum temperatures for canola growth (20.0°C to 22.0°C; [26,10,11], resulting in a longer growth cycle. Crop growth accelerated in the first cycle and DM yield decreased in response to the higher temperature levels recorded (24.5°C to 29.2°C).

Lower DM canola yields as compared to those of oat in the September sowings suggest that canola, mainly the cultivar Hyola 401, showed a greater susceptibility to high temperatures. As temperatures decreased in the October sowing dates (Fig. 1), canola IMC 205 increased its DM yield potential with a longer growth cycle (Figs. 3(a) and 3(b)). Canola Hyola 401 was only able to equal oat DM yield in the October 23 sowing date during the 2012-2013 cycle (Tab. 3), which presented lower ambient temperatures during growth cycle (Fig. 2(a)).

4.4 Early Sowing Dates Importance

Early sowing dates could be an efficient alternative for canola forage production during the autumn-winter cycle in the study region. Because of its precocity, it is feasible to establish a second crop during December, thus reducing one irrigation in comparison to those required by oat [5]. In order to obtain an early canola harvest during the autumn-winter period (November and December), it is necessary to have early sowing dates (September and October). Canola presented a lower DM yield in the September 11 sowing date, because high temperatures and long photoperiods accelerated crop growth. However, as of the September 25 sowing date, the canola IMC 205 cultivar produced similar yields to oat, when a longer growth cycle was used. As for canola nutrient yields, this forage potentially competes with oat forage for the first sowing date (September 11), and may even exceed it as of the second sowing date (September 25). This is mainly due to canola presenting a higher CP content than oat, in addition to exhibiting good NE_L concentration.

5 Conclusions

Canola forage potential evaluation in different sowing dates indicated that the best period to establish this forage in the study area is from September 25 to October 23, although this might vary according to the cultivar to be used. As of September 25, canola IMC 205 had DM and NE_L yields similar to those of oat, while canola Hyola 401 only reached them until the October 23 sowing date, when ambient temperatures were lower. Canola presented other nutrient production advantages when compared to oat, such as greater CP concentration and lower NDF and ADF contents. Therefore, canola represents a good forage alternative to oat for early sowings in the La Laguna area, northern México.

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