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Technical note

# Yield and nutritional value of forage brassicas compared to traditional forages

David Guadalupe Reta Sánchez [a*]

Juan Isidro Sánchez Duarte [b]

Esmeralda Ochoa Martínez [b]

Ana Isabel González Cifuentes [c]

Arturo Reyes González [b]

Karla Rodríguez Hernández [b]

[a] Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP). Campo Experimental Delicias. Km. 2 Carretera Delicias-Rosales. 33000, Centro, Cd. Delicias, Chihuahua, México.

[b] INIFAP. Campo Experimental La Laguna. Matamoros, Coahuila, México.

[c] Universidad Juárez del Estado de Durango. Facultad de Agricultura y Zootecnia. Gómez Palacio, Durango, México.

*Corresponding author: reta.david@inifap.gob.mx

**Abstract:**

The high nutritional value of brassicas can increase productivity in traditional forage production systems. The objective of the study was to compare the nutritional value and yield of dry matter (DM) and nutrients between forage brassicas and traditional autumn-winter species. The forage brassicas were Winfred, Hunter and Graza radish and the traditional forages were oats, triticale, barley, wheat and berseem clover. The study was conducted in Matamoros, Coahuila, Mexico in the 2018-2019 cycle, under a randomized complete block experimental design with four repetitions. The regrowth capacity, the nutritional composition of the forage and the yields of DM and nutrients were determined. All species showed regrowth capacity, with three cuts in berseem clover in 154 d, and with two cuts in brassicas (150-154 d) and cereals (133-144 d). The brassicas had nutritional composition similar to that of berseem clover and better than that of cereals, mainly due to their higher content of net energy of lactation ($NE_L$; 6.57 to 7.32 MJ $kg^{-1}$ DM). The DM yields of the brassicas were similar to those observed in traditional forages; however, due to their high nutritional composition, the brassicas were equal to or superior in production of crude protein (CP) (1,608 to 2,986 kg $ha^{-1}$) and $NE_L$ (62,819 to 84,044 MJ $ha^{-1}$) to traditional forages. In general, forage brassicas can increase nutrient yield with respect to cereals and berseem clover, especially in the production of $NE_L$ (27.5 to 47.3 %).

**Key words:** Alternative crops, Dry matter, Regrowth, Crude protein, Energy.

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Intensive cow’s milk production is one of the main economic activities in the Comarca Lagunera, Mexico. The forage required by livestock is produced in a production system where the main crops are corn, sorghum, alfalfa, oats and triticale. The production of these crops faces problems of water scarcity, salinity in the soil and high environmental temperatures(1), conditions that will worsen in the next decades due to climate change(2). This situation makes it necessary to look for new crop options that allow increasing the nutritional value and yields of dry matter and nutrients. An alternative is to increase forage production in autumn-winter using species with regrowth capacity, and good nutritional and production characteristics.

In the Comarca Lagunera, cereals in autumn-winter are produced with one or two cuts in the stages of booting or beginning of heading, which are usually ensiled. Forage brassicas that include species of canola, rapeseed, turnips, suede, kale and radish are a viable alternative for the region due to their production potential, nutritional quality, in addition to their capacity for regrowth(3,4) and silage of their forage(5,6). Brassicas produce 8,000 to 15,000 kg $ha^{-1}$ of dry matter (DM) in a period of 80 to 150 days after sowing (das). This means that their DM yields may be equal to or higher than autumn-winter forage cereals(3,7). The main benefit of the brassicas is their ability to produce forage with high nutritional value for a relatively long period, since the crude protein (CP) content and the digestibility of DM(8) do not decrease markedly with age. The CP content in brassica forage varies from 134 to 255 g $kg^{-1}$; the digestibility of DM fluctuates from 85 to 93 %(8,9); the neutral detergent fiber (NDF) content reaches values from 199 to 516 g kg$^{-1}$(9,10); and it has high concentrations of energy ($NE_L$) (1.79 to 1.87 Mcal kg$^{-1}$ DM)(11).

In studies with stabled dairy cows, it is indicated that brassica forage can be used in the diet of dairy cows without effects on milk production and composition(12,13). Other studies show positive effects of brassica forage with increases in milk production, without negative effects on cow health(14,15). In addition, in studies where the inclusion of brassica forage did not affect milk production and composition, an increase in profitability was observed when pasture silage and commercial concentrates were replaced with forage brassicas(15,16). It is also reported that the use of brassica forage has a favorable environmental effect due to the lower methane production compared to ruminants fed on pasture-based diets(11,17). The objective of the study was to compare the nutritional value and yield of dry matter (DM) and nutrients between forage brassicas and traditional species during the autumn-winter cycle.

The study was carried out at the La Laguna Experimental Station (CELALA, for its acronym in Spanish) of the National Institute of Forestry, Agricultural and Livestock Research (INIFAP, for its acronym in Spanish), located in Matamoros, Coahuila, Mexico (103° 13’ 42” W and 25° 31’ 41” N, at an altitude of 1,100 m asl). The soil of the experimental site has a clayey-loamy texture, with a depth greater than 1.8 m, water availability values of 150 mm m$^{-1}$(18), organic carbon content of 0.75 % and a pH of 8.14(1). The preparation of the land consisted of a fallow, double harrowing and leveling of the terrain with laser. Before sowing, each experimental plot was manually fertilized with granular ammonium sulfate and monoammonium phosphate at doses of 50 kg N and 80 kg $P_2O_5$, respectively.

Sowing was done manually on October 12, 2018, on this date, sowing irrigation with a 15 cm irrigation sheet was also applied. Eight days after sowing, an overirrigation with a 6 cm sheet was applied to facilitate the emergence of seedlings. The species and cultivars evaluated were the following: oats (*Avena sativa* L.), Cuauhtémoc variety; triticale (x *Triticosecale* Wittmack), Río Nazas variety; barley (*Hordeum vulgare* L.), Narro 95 variety; wheat (*Triticum aestivum* L.), AN265 variety; berseem clover (*Trifolium alexandrinum* L.), Multicut variety; brassica, Winfred cultivar (*Brassica oleracea* L. x *Brassica rapa* L.); Hunter cultivar (*Brassica rapa* L. x *Brassica napus* L.) and forage radish, Graza cultivar (*Raphanus sativus* L. x *Brassica oleracea* L., *Raphanus maritimus* L.). During the production cycle, six supplemental irrigations with a total sheet of 75 cm were applied in oats, triticale, wheat, clover, and Hunter brassica; while in barley, Winfred brassica and Graza radish, five supplemental irrigations with a sheet of 63 cm were applied. The nitrogen fertilization dose (250 kg ha$^{-1}$) was also completed with 55 kg ha$^{-1}$ at 33 das, 90 kg ha$^{-1}$ after the first cut in each species between 77 and 112 das, and 55 kg ha$^{-1}$ before the second cut between 112 and 135 das.

A randomized complete block experimental design with four repetitions was used. The experimental plot consisted of 20 furrows 0.18 m apart and 6 m long. The useful plot for determining forage yield was 14.4 $m^2$, harvesting 16 central furrows of 5 m in length. At harvest, fresh forage and DM yields were determined. The DM content was obtained in a random sample of 0.72 $m^2$, sampling two of the central furrows of each plot of 2 m in length. The sampled plants were dried at 60 °C in a forced-air oven until reaching constant weight.

DM yield was determined by multiplying the fresh forage yield by the DM content of each plot. In cereals, two harvests were made in the booting stage; clover was harvested three times in the vegetative stage, while the cultivars of brassica and radish were harvested twice in the vegetative stage. The leaf area index (LAI) was determined weekly in all plots of the experiment. For this, an AccuPAR ceptometer model Lp-80 PAR/LAI (Decagon Devices, Inc., Pullman, WA, USA) was used. Three readings per plot were taken between 1200 and 1400 h solar time. Three measurements were made above and below the canopy, parallel to the soil surface. The sensor was placed at an angle of 45° with respect to the furrows.

Plants sampled for the determination of DM content were also used to analyze the nutritional value of forage. The dry samples were ground in a Wiley® mill (Thomas Scientific, Swedesboro, NJ, USA) with a 1 mm mesh. The nitrogen content in each sample was determined using the Dumas combustion method number 990.03 of AOAC, in which the Thermo Scientific Flash 2000 equipment was used, and the result was multiplied by 6.5 to obtain the percentage of crude protein (CP)[19]. The neutral detergent fiber (NDF) and the acid detergent fiber (ADF) were obtained according to Goering and Van Soest[20]. The content of net energy of lactation ($NE_L$) was estimated following the methodology proposed by Weiss *et al*[21]. CP and $NE_L$ yields per hectare were determined by multiplying the CP and $NE_L$ contents by the DM yield per hectare estimated for each experimental plot.

For the evaluation of regrowth capacity, the data on DM yield and LAI were analyzed by harvest, using the MIXED procedure for repeated measurements of SAS ($P \leq 0.05$)[22]. For DM, CP and $NE_L$ yields, data from the two or three harvests in each crop were added together to perform the statistical analysis. For the data on the nutritional value of the forage, a weighted average of each parameter evaluated in the harvests carried out was obtained, considering the DM yields. Analyses of variance ($P \leq 0.05$) were performed for the variables of nutritional composition and yields of DM and nutrients. The means of these parameters were compared with the protected Fisher's least significant difference test ($P \leq 0.05$). The analysis of the information was performed with the SAS[22] statistical program.

All the species evaluated had regrowth capacity, but berseem clover was superior with three cuts in 156 days. The rest of the species produced two cuts; where the alternative species Winfred brassica, Hunter brassica and Graza radish required the total available period (150 to 154 d); while cereals produced the cuts between 133 and 144 d. This behavior of cereals allows starting earlier the preparation of the land for the next crop in the spring cycle. However, if this is not so important in the production system, the later harvest of alternative crops does not represent a disadvantage in the use of irrigation water, since these crops required less or equal irrigation sheet than that used in cereals (63 to 75 cm of water sheet).

The regrowth capacity of the hybrids of brassica and the forage radish for the production of two or three harvests in this study has also been observed in other works, where it is indicated that several grazings can be carried out in these crops[3,4]. Their good regrowth capacity is observed in the little or no reduction of the LAI in regrowth and the higher yields of DM in regrowths compared to the first harvest in Winfred brassica, Hunter brassica and Graza radish (Table 1).

**Table 1:** Growth cycle, dry matter yield recovery (DMY) and leaf area index (LAI) at regrowth after the first cut in traditional and alternative crops evaluated in the autumn-winter cycle of 2018-2019

| **Treatments** | **Cycle (days)** | **DMY (kg ha$^{-1}$)** | | | **LAI** | | |
|---|---|---|---|---|---|---|---|
| | | **Cut 1** | **Cut 2** | **Cut 3** | **Cut 1** | **Cut 2** | **Cut 3** |
| Cuauhtémoc oat | 144 | 4694 $^{a}$ | 6550 $^{a}$ | - | 6.08 $^{a}$ | 4.48 $^{b}$ | - |
| Río Nazas triticale | 141 | 3718 $^{b}$ | 5684 $^{a}$ | - | 4.20 $^{a}$ | 3.55 $^{a}$ | - |
| Narro 95 barley | 133 | 4089 $^{a}$ | 5697 $^{a}$ | - | 5.98 $^{a}$ | 5.76 $^{a}$ | - |
| AN265 wheat | 144 | 4779 $^{a}$ | 6534 $^{a}$ | - | 5.64 $^{a}$ | 2.92 $^{b}$ | - |
| Berseem clover | 156 | 3924 $^{a}$ | 4183 $^{a}$ | 2094 $^{b}$ | 3.65 $^{b}$ | 6.19 $^{a}$ | 3.10 $^{b}$ |
| Winfred brassica | 150 | 4586 $^{b}$ | 7430 | - | 7.20 $^{a}$ | 6.26 $^{b}$ | - |
| Hunter brassica | 154 | 3391 $^{a}$ | 5178 | - | 5.82 $^{a}$ | 6.30 $^{a}$ | - |
| Graza radish | 154 | 4483 $^{a}$ | 5999 | - | 6.44 $^{b}$ | 8.03 $^{a}$ | - |

[ab] Means followed by different letters in each row are significantly different (Tukey-Kramer $P \leq 0.05$).

The regrowth capacity observed in traditional crops is in accordance with what is commonly observed in other studies carried out in the Comarca Lagunera. In berseem clover, it has been reported that the Multicut variety produces up to 13.1 t ha$^{-1}$ of DM in six cuts[23]. In cereals such as triticale, oat and barley, it has been observed that they have good capacity to regrowth[24,25], with two to three cuts[26]. Generally, greater capacity is observed in winter genotypes, followed by facultative ones and lower in spring ones[27,28]. In the present study, the spring cultivars of Cuauhtémoc oat, Río Nazas triticale and Narro 95 barley had regrowth capacity similar to that observed in the facultative wheat AN265, which had a lower recovery of LAI due to its later growth cycle. This represents a disadvantage in an intensive forage production system, since AN265 wheat did not reach its maximum growth in regrowth as spring cereals did.

Of the traditional crops, berseem clover had the best forage nutritional composition, with lower concentrations of NDF (417 g $kg^{-1}$) and ADF (289 g $kg^{-1}$), as well as higher contents of CP (286 g $kg^{-1}$) and $NE_L$ (6.44 MJ $kg^{-1}$ DM) with respect to the values observed in all cereals. Among cereals, Rio Nazas triticale was outstanding for its lower ADF content (372 g $kg^{-1}$), and higher concentrations of $NE_L$ (5.52 MJ $kg^{-1}$ DM) and CP (189 g $kg^{-1}$) (Table 2).

**Table 2:** Nutritional composition of traditional and alternative crops evaluated in the autumn-winter cycle of 2018-2019

| **Treatments** | **CP (g $kg^{-1}$)** | **NDF (g $kg^{-1}$)** | **ADF (g $kg^{-1}$)** | **$NE_L$ (MJ $kg^{-1}$ DM)** |
|---|---|---|---|---|
| Cuauhtémoc oat | 148.7 $^{d}$ | 612.3 $^{a}$ | 395.8 $^{c}$ | 5.27 $^{e}$ |
| Río Nazas triticale | 189.1 $^{c}$ | 606.6 $^{a}$ | 372.2 $^{d}$ | 5.52 $^{d}$ |
| Narro 95 barley | 204.7 $^{c}$ | 567.3 $^{b}$ | 488.7 $^{a}$ | 4.27 $^{g}$ |
| AN265 wheat | 165.1 $^{d}$ | 628.6 $^{a}$ | 418.7 $^{b}$ | 5.02 $^{f}$ |
| Berseem clover | 286.4 $^{a}$ | 417.1 $^{d}$ | 288.6 $^{e}$ | 6.44 $^{c}$ |
| Winfred brassica | 248.8 $^{b}$ | 431.3 $^{d}$ | 239.5 $^{f}$ | 6.99 $^{b}$ |
| Hunter brassica | 187.8 $^{c}$ | 277.0 $^{e}$ | 210.4 $^{g}$ | 7.32 $^{a}$ |
| Graza radish | 198.4 $^{c}$ | 456.6 $^{c}$ | 280.7 $^{e}$ | 6.57 $^{c}$ |

CP= crude protein; NDF= neutral detergent fiber; ADF= acid detergent fiber; $NE_L$= net energy of lactation; DM= dry matter.

†Means followed by different letters in each column are significantly different (MSD $P \leq 0.05$).

The alternative crops, brassicas and radish, had a better nutritional composition than that observed in cereals, due to their high CP content, lower fiber concentration and higher $NE_L$ content. In CP concentration, Winfred brassica (249 g $kg^{-1}$) exceeded cereals (149 to 205 g); while Hunter brassica (188 g) and Graza radish (198 g) obtained values similar to or higher than those observed in cereals. In berseem clover, the CP content (286 g $kg^{-1}$) was higher than that observed in the alternative crops, while in concentration of $NE_L$, Winfred brassica and Graza radish (6.57 to 6.99 MJ $kg^{-1}$ DM) were higher than that obtained in berseem clover (Table 2).

The results of the nutritional composition of the present study in the forage of brassicas and radish were within the typical range observed in forage brassicas of other works, which were characterized mainly by their high contents of CP (134 to 255 g $kg^{-1}$)[8,9] and $NE_L$ (7.49 to 7.82 MJ $kg^{-1}$ of DM)[11]. However, in this study in Winfred brassica and Graza radish, higher ADF and NDF contents than those obtained in previous studies were observed, with ADF values of 118 to 217 g $kg^{-1}$ and 166 to 334 g in NDF[10,11,29]. It has been indicated that these NDF concentrations do not meet the minimum values for the proper functioning of the rumen in cows (350 g)[30]. In the present study, NDF values in Winfred brassica (431 g) and Graza radish (457 g) were greater than 350 g, and similar to those observed in berseem clover (417 g); while in Hunter brassica (277 g), NDF values were lower than this amount. The high content of $NE_L$ in the forage of Hunter and Winfred brassicas, Graza radish and berseem clover was associated with the lower contents of ADF and NDF, in relation to the values observed in cereals harvested in the booting stage.

The alternative crops, Winfred brassica and Graza radish, were outstanding in DM yield (12,016 to 10,482 kg $ha^{-1}$). These yields were similar to those obtained by berseem clover (10,201 kg) and to the best cereals, Cuauhtémoc oat, Narrro 95 barley and AN265 wheat (9,786 to 11,313 kg). In nutrient production, only berseem clover obtained CP yields (2,871 kg) similar to those of Winfred brassica (2,986 kg), the rest of the crops obtained lower CP yields (1,608 to 2,082 kg). In yield of $NE_L$, Winfred brassica (84,044 MJ) exceeded all other crops evaluated (from 41,689 to 68,722 MJ $ha^{-1}$) (Table 3).

**Table 3:** Yields of dry matter (DM), crude protein (CP) and net energy of lactation ($NE_L$) in traditional and alternative crops evaluated in the autumn-winter cycle of 2018-2019

| **Treatments** | **DM (kg ha$^{-1}$)** | **CP (kg ha$^{-1}$)** | **$NE_L$ (MJ ha$^{-1}$)** |
|---|---|---|---|
| Cuauhtémoc oat | 11244 $^{ab}$ | 1672 $^{b}$ | 59442 $^{bc}$ |
| Río Nazas triticale | 9402 $^{bc}$ | 1781 $^{b}$ | 52074 $^{cd}$ |
| Narro 95 barley | 9786 $^{abc}$ | 1996 $^{b}$ | 41689 $^{d}$ |
| AN265 wheat | 11313 $^{ab}$ | 1854 $^{b}$ | 57045 $^{bc}$ |
| Berseem clover | 10201 $^{abc}$ | 2871 $^{a}$ | 65923 $^{bc}$ |
| Winfred brassica | 12016 $^{a}$ | 2986 $^{a}$ | 84044 $^{a}$ |
| Hunter brassica | 8569 c | 1608 $^{b}$ | 62819 $^{bc}$ |
| Graza radish | 10482 $^{abc}$ | 2082 $^{b}$ | 68722 $^{b}$ |

$^{abc}$ Means followed by different letters in each column are significantly different (MSD $P \leq 0.05$).

The DM yields obtained in the brassicas with two cuts are similar to the best yields reported in other studies in brassicas (10,134 to 14,000 kg ha$^{-1}$)[31,32]. This level of yield in brassicas, and their higher contents of CP and $NE_L$ with respect to cereals resulted in higher yields of these nutrients per hectare. In relation to berseem clover with a high CP content, the brassicas obtained similar CP yields for their high DM yield; however, in $NE_L$ yields, Winfred brassica was superior to all species as a result of a combined effect of a high $NE_L$ content (Table 2) and a high DM production (Table 3).

An aspect to highlight in the study was the ability of forage brassicas to produce yields of DM and nutrients similar to or greater than those obtained with traditional species, with irrigation sheets (63 to 75 cm) less than or equal to those used in traditional crops. These results are important in a forage production system such as that of the Comarca Lagunera, which has a shortage of water for irrigation.

In conclusion, forage brassicas have the potential to increase productivity in forage production in autumn-winter due to their high nutritional value, good regrowth capacity and high production of DM and nutrients. Of the species evaluated, Winfred brassica was outstanding with respect to traditional crops mainly due to its higher content and production of $NE_L$ (27.5 to 47.3 %).

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