Alternative Forages for Dairy Farming Systems

Gonzalo Ferreira[1]
Department of Dairy Science
Virginia Tech

Summary

Many forage sources exist that are considered alternatives to corn silage and alfalfa hay or alfalfa silage, and the growing of alternative forages in more marginal lands and feeding of alternative forages to livestock may become more critical in a near future. Under a financial perspective, the best alternative forage may be the one that allows the farmer or nutritionist to formulate the cheapest ration possible while meeting the requirements of the animal. Under agronomic and logistic perspectives, the best alternative forage may be the one a farmer can grow according to the limitations of the environment (i.e., soil and weather) or the one a farmer can purchase according to the geographical location of the farm. Overall, depending on what the goals of the farm are, most alternative forages can be used in dairy farming systems. A holistic approach that considers the forage production, the forage quality, the animal performance, and the sustainability of the system is critical to better select a forage production and feeding program for dairy farming systems.

Introduction

In the US, corn silage and alfalfa hay or alfalfa silage are the main forage sources for feeding cattle in dairy farming systems. However, many other forage sources exist that are considered alternatives to corn silage and alfalfa hay or alfalfa silage. These alternative forages include summer annual grasses, such as sorghum and pearl millet, and winter annual grasses, such as barley, oats, rye, triticale, or wheat. Other annual or perennial forages are also considered alternative forages (e.g., hairy vetch, crimson clover, orchard grass, and fescue, to mention a few).

Given they have a great nutritional quality, corn silage and alfalfa hay or silage are the top choice for nutritionist when formulating diets for lactating dairy cows. However, under certain circumstances, the limited availability of corn silage or alfalfa hay or alfalfa silage challenges farmers and nutritionists to incorporate alternative forages into rations for lactating dairy cows. Even more, in the context of an increasing population and a decreasing amount of crop land, the growing of alternative forages in more marginal lands and feeding of alternative forages to livestock may become more critical in a near future.

The purpose of this manuscript is to revise some concepts relevant to the cropping and feeding of alternative forages that hopefully will help farmers and nutritionists to consider alternative forages as common tools for feeding cattle in dairy farming systems.

[1]Contact at: 175 W Campus Drive, Blacksburg, VA 24060; Office: (540) 231-1965; e-mail: gonf@vt.edu.

Definitions of Alternative Forages

Even though the term alternative forage has been used for years (Angirasa et al., 1985; Kochapakdee et al., 1997), finding a clear definition for alternative forages is not easy. The word alternative implies that a subject or an object is available as another possibility to an existing one. In the US, corn silage and alfalfa hay or alfalfa silage are the most popular forages utilized for feeding dairy cattle, and these two forages are, therefore, considered the top-choice forages. Given their high yield of good quality forage, corn and alfalfa are also known, respectively, as the king and the queen of forages (Lauer, 2019). If we consider that corn and alfalfa are the top-choice forages, then any forage other than corn and alfalfa can be considered an alternative forage (Kochapakdee et al., 1997; Alemu and Doepel, 2011).

Under a cropping context, summer annual grasses, such as sorghum and pearl millet, are considered alternative forage crops to corn. Similarly, a perennial pasture of orchardgrass and red clover or an annual grazing soybean are considered alternative forage crops to alfalfa. In these cases, certain agronomic or management reasons might drive the use of alternative forage crops. However, certain alternative forages are not necessarily alternative forage crops. For example, winter annual grasses grown in monoculture or mixed with legumes (Brown et al., 2018; Coblentz et al., 2018b; Coblentz and Ottman, 2022) are also considered alternative forages. However, these crops are not grown as alternative crops to corn or alfalfa but rather as complement crops to increase forage production, to sustain nutrient management plans, or to promote soil health as cover crops (Brown et al., 2018; Lyons et al., 2019). Also, under a feeding perspective, other forages fed to cattle, such as mixed grass hay (Ferreira and Teets, 2020) or wheat straw (Coblentz et al., 2018a; Havekes et al., 2020), are also considered alternative forages.

Why Are Alternative Forages Needed?

The reasons for needing alternative forages in a dairy farming system are multiple and diverse. If a need exists to maximize forage production, then fitting multiple crops in a cropping cycle might increase forage production. For example, a double-cropping system in which a winter annual crop is grown and harvested for silage before planting, growing, and harvesting a summer annual crop may be possible in certain areas, although not always occur (Krueger et al., 2012; Brown et al., 2018; Lyons et al., 2019). In areas where a double-cropping system fits the rotation, the winter crop might increase forage production (Lyons et al., 2019), might reduce nutrient leaching (Krueger et al., 2012), or can be utilized as a cover crop to reduce soil erosion (Krueger et al., 2012). The use of double-crops, however, should be analyzed and measured carefully as double-cropping does not always result in greater forage production than when a single crop is grown (Figure 1).

Another reason for growing alternative forage crops is to attenuate the negative impacts of environment on forage production. For example, given the lower water requirements and the greater tolerance to higher temperatures (Brown and Funk, 2008), sorghum may be a better-suited crop than corn for growing in certain areas where heat or drought stresses commonly occur. Caution should be taken, however, because sorghum crops do not necessarily yield more biomass than corn crops in areas where abiotic stresses are common (Marsalis et al., 2010; Ferreira et al., 2016). For example, using a database from 2008 to 2018, Ferreira et al. (2016) reported greater yields of dry matter **(DM)** for corn than for sorghum while grown in Florida (Table 1).

Lowering input costs is another reason for growing alternative forages. For example, given that the cost of sorghum seed can be half (or even less) than the cost of corn seed ($20 to $50/acre and $100 to $150/acre for forage sorghum and corn, respectively), planting forage sorghum might be tempting for farming systems under financial stress. Clearly, the difference in input costs between these two forages will depend on the varieties compared, and the quality of the forages obtained might not be comparable (discussed further below). This being said, farmers should be cautious with this concept because, due to differences in the nutritional qualities of corn and sorghum, the total cost of the feeding program might end up being greater for corn than for sorghum (Richardson and Ferreira, 2017).

Finally, alternative forages might be needed in dairy farming systems as a means to meet the requirements of the animals. For example, mixed-grass hay or wheat straw might be included in rations to supply fiber to lactating cows or to restrict energy in rations for animal requiring low concentrations of energy (Coblentz et al., 2018a; Ferreira and Teets, 2020; Havekes et al., 2020).

Best Alternative Forage?

"Which forage is the best forage?" might be a frequent question asked by farmers to those who commonly interact with them through consulting or Extension service. This question can be answered from at least two perspectives. Under a financial perspective, the best forage or alternative forage may be the one that allows the farmer or nutritionist to formulate the cheapest ration possible while meeting the requirements of the animal. In this regard, when cheap fiber and energy are needed, corn silage would likely be the top-choice forage. Alternatively, when cheap fiber and protein are needed, alfalfa hay might be the top-choice forage. There are other circumstances, however, in which forages commonly defined as of poor quality (e.g., mixed-grass hay or sorghum silage) might be convenient to include in rations. Mixed-grass hay may become a very convenient forage source, for example, when low-forage diets need to be formulated because the inventory of corn silage is not sufficient to reach the following harvest (Ferreira and Teets, 2020).

Under an agronomic and logistic perspective, the best forage or alternative forage may be the one a farmer can grow according to the limitations of the environment (i.e., soil and weather) or the one a farmer can purchase according to the geographical location of the farm. Under this perspective, forage sorghum may be considered a much better option to grow than corn in the southern Great Plains region. Also, in areas where alfalfa hay is very expensive, like in the mid-Atlantic region, good quality alfalfa hay might not be the top-choice forage, despite its great forage quality (Ferreira and Teets, 2020).

Bottom line, depending on the circumstances, any alternative forage can be considered a good forage. It cannot be denied that corn silage and alfalfa hay or alfalfa silage can be considered the best forages for dairy farming systems. After all, corn silage and alfalfa hay or alfalfa silage are considered the king and queen of forages, respectively (Lauer, 2019), and we know that great production levels can be expected when feeding these forages. The key question is how different can be animal performance when feeding alternative forages.

Sorghum Silage for Lactating Dairy Cows

Differences in DM yield and nutritional quality should be expected between corn and sorghum crops for silage. In a retrospective study, Ferreira et al. (2016) compared the dry matter yield and the nutritional composition of corn, forage sorghum, and sorghum sudan crops (all of these as whole plant for silage) that were grown during the spring and summer seasons in Florida (Table 1). Throughout those years, crops grown during the spring yielded 30 to 35% more than crops grown during the summer (8.9 vs. 6.1 ton/acre for corn, 7.8 vs. 5.4 ton/acre forage sorghum, and 8.6 vs. 5.4 ton/acre for sorghum sudan). In regard to forage type, corn yielded 10% more than both sorghum crops (7.5 vs. 6.8 ton/acre), and DM yield did not differ between sorghum crops. Corn had the least concentration of NDF (42.9%), forage sorghum had an intermediate concentration of NDF (56.1%), and sorghum sudan had the greatest concentration of NDF (58.9%). In terms of NDF digestibility (NDFD), corn had the greatest NDFD (56.1% of NDF), forage sorghum had an intermediate NDFD (50.7%), and sorghum sudan had the least NDFD (46.7%). Regarding starch concentration, corn had a greater concentration of starch (32.8%) than both sorghum crops, which had similar starch concentrations (14.7%). All these observations reinforce the concept that corn silage is the king of forages (Lauer, 2019). However, despite the inferior nutritional quality of sorghum silage, interest still exists among farmers for including sorghum silage in feeding programs for dairy cattle. Reasons for this interest are the greater tolerance to drought stress and its lower input costs.

Because sorghum silage can likely have inferior nutritional quality than corn silage, some reluctance might be found to use sorghum silage in diets for high-producing dairy cattle. However, the existence of forage sorghum materials containing the brown midrib **(BMR)** mutation can minimize these nutritional differences. For example, Sanchez-Duarte et al. (2019) performed a meta-analysis and reported that milk yield and DM intake were similar among cows consuming conventional corn silage or BMR sorghum silage. In another study, Yang et al. (2019) replaced all the conventional corn silage with a BMR forage sorghum silage while feeding high-producing dairy cows (Table 2). In this case, cows consuming diets containing corn silage produced more milk than cows consuming diets containing sorghum silage (114 vs. 108 lb/day, respectively). However, milk from cows consuming diets containing sorghum silage contained a greater concentration of fat than milk from cows consuming diets containing corn silage (3.84 vs. 3.30% fat, respectively). In agreement with these observations, Sanchez-Duarte (2019) reported in their meta-analysis that the milk from cows consuming BMR forage sorghum silage contained 0.10% more fat than milk from cows consuming conventional corn silage. These differences in milk fat concentration are not trivial observations, especially in regions where milk prices are determined by fat and skim milk concentrations. Contrary to this, Sanchez-Duarte et al. (2019) reported that milk from cows consuming diets containing sorghum silage contained 0.06% less protein than milk from cows consuming diets containing corn silage. Yang et al. (2019) did not observe a reduction in milk protein concentration when cows were fed BMR forage sorghum silage. Even more, the 3.5%-energy-corrected milk production did not differ between cows consuming diets containing either corn or sorghum silage (Yang et al., 2019). In regard to DM intake, while Sanchez-Duarte (2019) did not report differences, Yang et al. (2019) reported lower DM intakes for cows consuming BMR forage sorghum silage than for cows consuming corn silage (56 vs. 63 lb/day). Based on these studies, there are no critical reasons for not feeding sorghum silage to high-producing dairy cows if there is a need to do so (e.g., environmental challenges, financial limitations, etc.). The most important recommendation in this regard might be selecting a variety of sorghum hybrids containing the BMR mutation that can attenuate potential differences in DM intakes.

Mixed Grass Hay

When feeding high-producing dairy cows, including sufficient physically effective NDF from hay in the ration is a good strategy to ensure rumen health, optimize nutrient utilization, and increase milk fat concentration (Mertens, 1997). In the mid-Atlantic region of the United States, where the availability of alfalfa hay is limited, nutritionists and managers may be inclined to buy expensive alfalfa hay from far-away regions (e.g., Great Plains or Midwest) or to include locally-grown grass hay in the diet. Even though the latter alternative seems unfavorable when comparing hay quality on a DM basis, including grass hay in the ration may still be a less expensive alternative to alfalfa hay when considering specific nutrients, such as effective NDF.

To evaluate the inclusion of locally-grown mixed grass hay as an alternative forage to alfalfa hay, Ferreira and Teets (2020) used a least-cost formulation approach to evaluate the production performance of high-producing dairy cows consuming diets containing either alfalfa hay or grass hay, and they observed that feeding diets with grass hay resulted in less energy-corrected milk production (107 vs. 111 lb/day) and less DM intake (54 vs. 60 lb/day) than when feeding diets with alfalfa hay (Table 3). The lower performance of cows consuming diets containing grass hay was attributed to the greater inclusion of hay in the diet given its lower price. Despite the lower performance, feeding diets with grass hay instead of alfalfa hay increased income over feed costs from $7.68 to $8.39/cow/day. The increased income over feed cost was attributed to a less expensive diet that resulted in greater milk fat concentrations (4.22 vs. 3.89% fat; Table 3) and lower DM intake that compensated for the decrease in revenue due to lower milk production.

As nutritionists, we frequently claim that cows require nutrients and not ingredients (Ferreira and Teets, 2020). Therefore, as long as rations meet the requirements of the animals to be fed and comply with the least-cost formulation constraints, then there should not be major concerns to include mixed-grass hay in rations for high-producing dairy cows. Results from this (Ferreira and Teets, 2020) and other studies (Santana et al., 2019) may help challenging the misconception that grass hays have poor nutritional quality and are not suitable for feeding high-producing dairy cows. If evaluated based only on its low energy or protein concentrations, then grass hay could be considered a poor-quality alternative forage. However, grass hay can still be strategically included in the diet of high-producing dairy cows to ensure rumen health and optimize nutrient utilization, as grass hay may be a very good source of potentially digestible NDF. To highlight this, Ferreira and Teets (2020) showed that grass hay had a lower undegradable NDF concentration (NDF basis) than alfalfa hay (37.7 and 46.4%, respectively; Figure 2). The latter observation is confirmed by several other studies (Grant and Weidner, 1992; Van Soest, 1994; Santana et al., 2019).

Winter Annual Crops

Winter annual crops, also known as cereal crops, are used extensively in other countries for feeding lactating dairy cows (Arieli and Adin, 1994; Eun et al., 2004; Bikel et al., 2020). Wheat silage, for example, is typically fed as the only forage source in diets of high-producing dairy cows in Israel (Arieli and Adin, 1994; Bikel et al., 2020). Similarly, barley silage is typically fed as the main forage source in diets of lactating dairy cows in Canada (Eun et al., 2004). In the US, however, the inclusion of cereal silage in diets for lactating dairy cows has been a little more conservative (Harper et al., 2017).

As mentioned before, double-cropping systems may have a negative effect on total forage production depending on the conditions (Krueger et al., 2012). Because of the potential negative effect on the following summer annual crop (Figure 1), plenty of research on winter annual crops revolves around the effect of maturity at harvest on forage yield and the nutritional composition of the forage (Coblentz et al., 2018b; Coblentz and Ottman, 2022). In this regard, Coblentz et al. (2018b) observed that, while the DM yield is substantially greater (4.0 vs. 1.2 ton DM/acre) when the triticale crop is harvested at a soft-dough stage, the nutritional quality of the forage is much better when the triticale crop is harvested at the boot stage (5.8 vs. 13.8% CP, 58.0 vs. 49.5% NDF, and 0.67 vs. 0.70 Mcal NEL/lb DM, respectively).

Another aspect of interest related to winter annual grasses is the selection of species and varieties within species to be grown so that the maximum amount of good-quality forage is obtained. Table 4 depicts the yields and the nutritional composition of 2 varieties of rye, 2 varieties of barley, and 4 varieties of triticale grown at 3 locations in Virginia during 2021 (Ferreira, unpublished results). In general terms, rye and barley materials tended to reach harvesting time much earlier than triticale materials (data not shown), especially when harvested at the boot stage of maturity. Therefore, when the goal is to attenuate the negative impact of the winter annual crop on the following summer annual crop (Krueger et al., 2012), rye and barley might be the best choices. However, in systems where the production of DM needs to be maximized, then triticale might of the species of choice. As far as genetic selection, further research is needed to evaluate the selection of materials. This being said, it is worth highlighting that management decisions might have a much greater impact on forage quality than species or variety selection (Figure 3).

To finish, studies evaluating the effect of maturity at harvest of the cereal crop on milk production are scarce (Arieli and Adin, 1994). In this regard, Arieli and Adin (1994) reported that cows consuming a diet containing a wheat silage harvested at the flowering stage (presumably anthesis) produced more milk (79 vs. 72 lb/day) than cows consuming a diet containing a wheat silage harvested at a milky stage (i.e., harvested 11 days later). More feeding trials evaluating the effect of harvesting time on performance of lactating dairy cows are on-going at Virginia Tech, and results should be reported in the near future.

Conclusions

Depending on what the goals of the farm are, most alternative forages can be used in dairy farming systems. A holistic approach that considers the forage production, the forage quality, the animal performance, and the sustainability of the system (either economic, environmental, or social) is critical to better select forage production and feeding programs for dairy farming systems.

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Table 1. Effect of planting season on yield and composition of different corn (CN), forage sorghum (FS), and sorghum sudan (SS) for silage (Ferreira et al., 2016).

	Spring			Summer				Contrast (*P* value)[1]				
	CN	FS	SS	CN	FS	SS	SEM	1	2	3	4	5
DM Yield, ton/acre	8.9	7.8	8.3	6.1	5.4	5.4	0.46	0.01	0.02	0.75	0.57	0.48
DM, %	30.8	29.7	30.0	31.8	29.0	28.6	0.68	0.36	0.01	0.02	0.92	0.47
CP, % of DM	8.4	7.1	6.8	8.2	7.0	7.8	0.47	0.47	0.01	0.35	0.59	0.21
NDF, % of DM	41.8	55.9	58.9	43.9	56.3	58.8	1.15	0.12	0.01	0.26	0.01	0.46
NDFD, % of NDF	60.0	52.9	47.9	52.2	48.5	45.4	2.20	0.01	0.01	0.18	0.05	0.63
Starch, % of DM	34.3	17.3	16.5	31.3	14.1	10.8	2.39	0.01	0.01	0.52	0.26	0.51

[1]Contrast 1: Spring vs. Summer; Contrast 2: Forage Type (Corn vs. Sorghum); Contrast 3: Interaction of Season and Forage Type; Contrast 4: Sorghum Type (Forage Sorghum vs. Sorghum Sudan); and Contrast 5: Interaction of Season and Sorghum Type.
[2]NDFD = NDF digestibility.

Table 2. Production performance of cows consuming corn silage-based diets or brown midrib forage sorghum silage-based.[1]

	Corn	Sorghum	SEM	P <
Dry matter intake, lb/day	63	58	2.4	0.01
Milk yield, lb/day	104	98	4.4	0.01
Milk fat, %	3.30	3.83	0.14	0.01
Milk fat yield, lb/day	3.7	4.0	0.24	0.01
Milk protein, %	2.91	2.89	0.07	0.60
Milk protein yield, lb/day	3.3	3.0	0.09	0.01
Milk lactose, %	4.78	4.81	0.07	0.51
Milk lactose yield, lb/day	5.4	5.0	0.24	0.01
3.5%-fat-corrected milk yield, lb/day	109	111	5.3	0.25

[1]Adapted from Yang et al. (2019).

Table 3. Production performance of cows consuming diets containing alfalfa hay or grass hay.[1]

	Alfalfa	Grass	SEM	P <
Dry matter intake, lb/day	60	54	3.3	0.01
Milk yield, lb/day	105	98	3.6	0.01
Milk fat, %	3.89	4.22	0.21	0.01
Milk fat yield, lb/day	3.7	4.0	0.18	0.64
Milk protein, %	3.02	3.02	0.09	0.93
Milk protein yield, lb/day	3.2	2.9	0.11	0.01
Milk lactose, %	4.85	4.84	0.04	0.29
Milk lactose yield, lb/day	5.17	4.70	0.24	0.01
3.5%-fat-corrected milk yield, lb/day	111	107	3.6	0.02

[1]Adapted from Ferreira and Teets (2020).

Table 4. Dry matter yield and nutritional composition (DM basis) of winter annual grasses harvested at boot stage or soft-dough stage of maturity (Ferreira, unpublished).[1]

	DM Yield ton/acre	Ash %	CP %	NDF %	ADF %	ADL %	Starch %
Boot stage							
Barley 1	1.7	8.1	16.5	45.8	26.3	2.1	3.4
Barley 2	1.6	8.5	15.1	49.0	27.7	2.5	3.7
Rye 1	1.1	7.7	18.5	41.8	23.1	2.0	3.4
Rye 2	1.7	7.1	15.9	44.6	24.7	1.8	6.2
Triticale 1	2.1	6.3	12.3	47.3	25.6	2.3	6.9
Triticale 2	2.7	6.8	12.2	51.1	29.1	2.5	7.4
Triticale 3	2.4	6.8	11.9	50.8	28.1	2.5	7.2
Triticale 4	2.6	7.9	11.9	51.6	29.1	2.6	6.9
Soft-dough stage							
Barley 1	4.3	5.3	9.4	53.8	30.5	3.5	6.7
Barley 2	3.7	5.2	9.3	56.2	34.4	4.2	5.3
Rye 1	6.3	5.2	5.2	59.9	38.4	5.1	4.6
Rye 2	5.1	4.1	6.1	63.1	39.9	4.8	5.5
Triticale 1	5.1	3.4	6.4	53.6	32.2	4.0	8.0
Triticale 2	4.9	3.4	5.6	63.2	39.6	5.6	7.2
Triticale 3	4.5	3.6	6.1	61.2	36.1	4.9	6.0
Triticale 4	5.6	4.0	6.2	63.7	34.9	5.2	6.2

[1]DM = Dry matter, CP = crude protein, NDF = nuetral detergent fiber, ADF = acid detergent fiber, and ADL = acid detergent lignin.

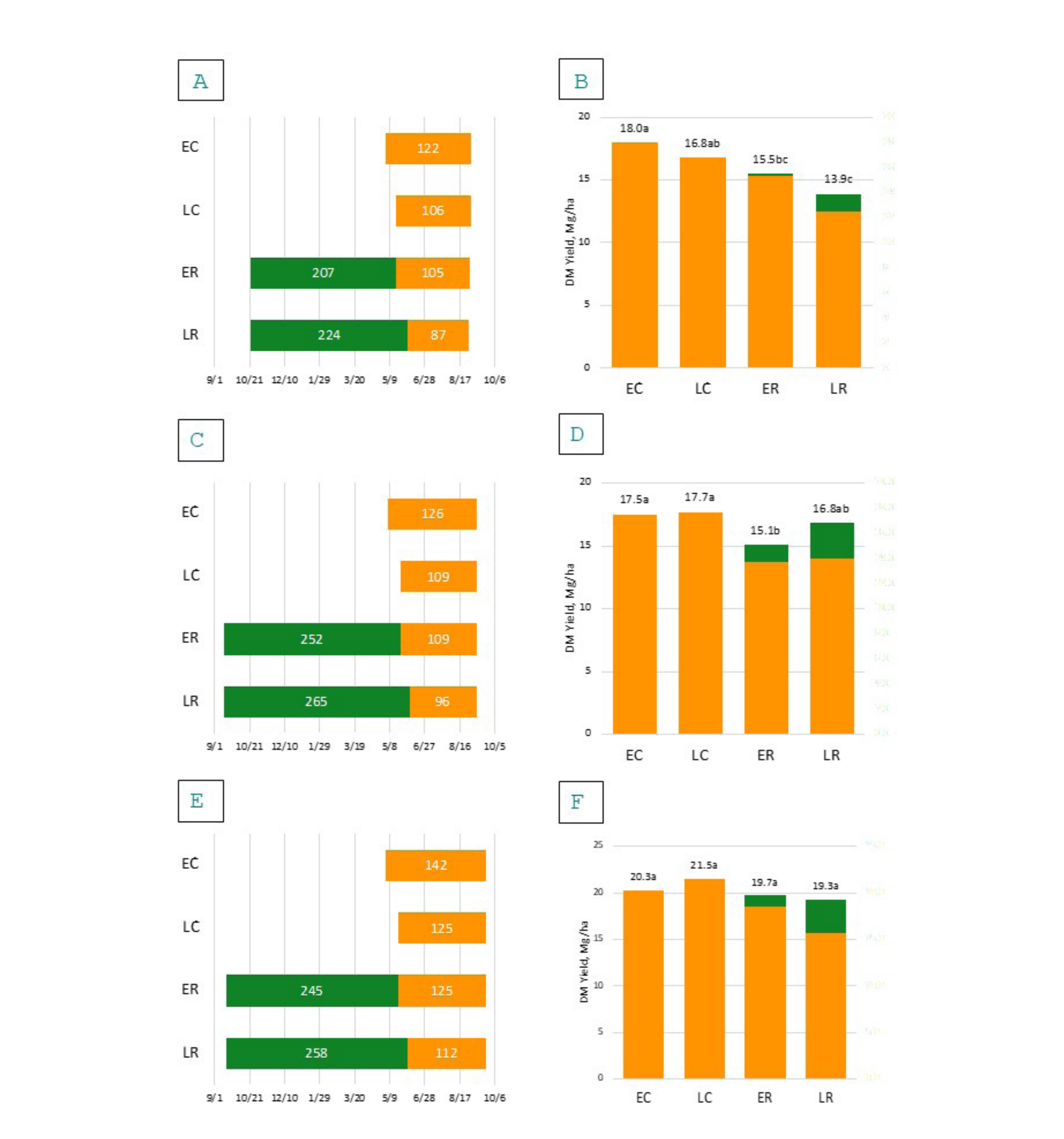

Figure 1. Forage yields (right) from 3 years based on a single-crop (corn only; orange) or double-crop (rye + corn) system (orange and green). Figures 2A, 2C, and 2E depict the growing days of the crops. Figures 2B, 2D, and 2F depict the yields of the crops. Data obtained from Krueger et al. (2012). EC = early corn, LC = late corn, ER = early rye, and LR = late rye; Mg/ha = 1 metric ton/ha = 1.1 US ton/ha.

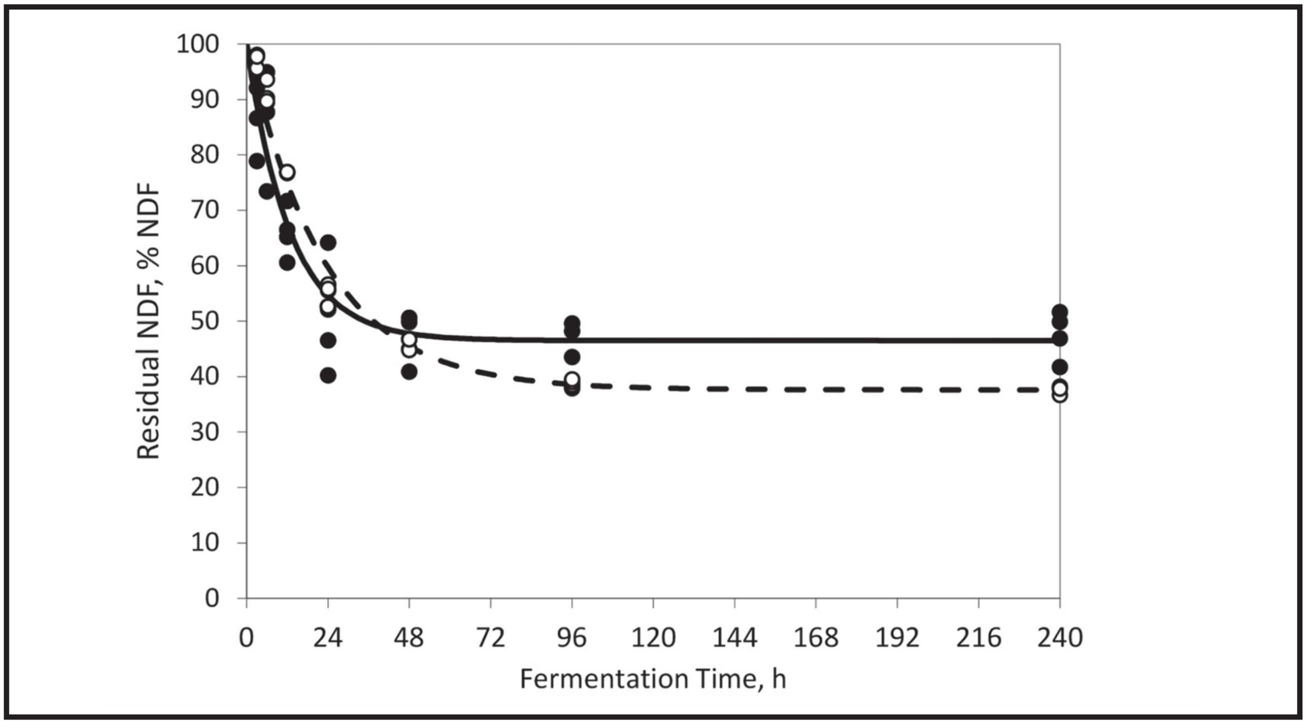

Figure 2. In vitro residual NDF of alfalfa (solid lines and solid circles) and grass (broken line and open circles) hays (Ferreira and Teets, 2020). Potentially digestible NDF (pdNDF), also known as fraction B, was 53.5 and 62.4% for alfalfa hay and grass hay, respectively. Fractional digestion rate (k) of pdNDF was 7.82 and 4.32%/hr per hour for alfalfa hay and grass hay, respectively.

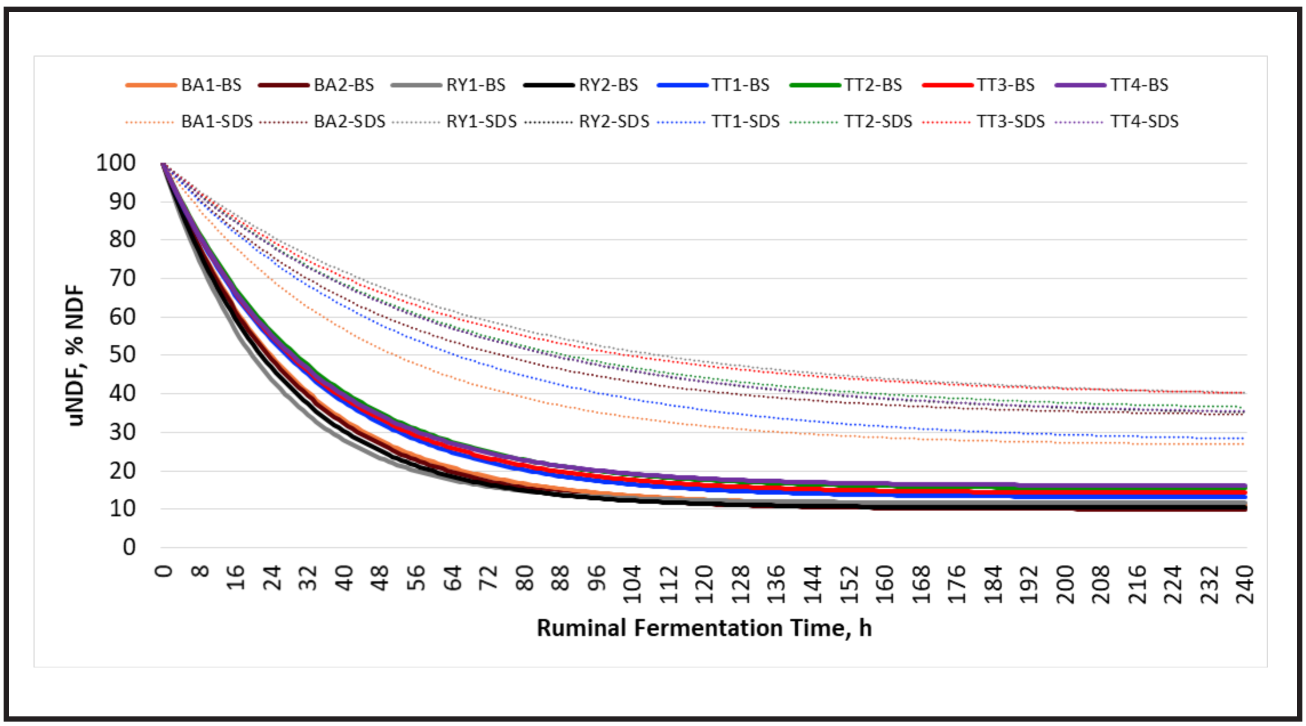

Figure 3. In situ ruminal NDF digestion kinetics of winter annual grasses harvested at boot stage (BS) or soft-dough stage (SDS). Winter annual grasses include 2 varieties of barley (BA), 2 varieties of rye (RY), and 4 varieties of triticale (TT). (Ferreira, (unpublished).