Short-term mixed pastures of *Lolium multiflorum*, *Avena sativa* and *Vicia sativa* or *Lolium multiflorum* × *Festuca pratensis, Avena strigosa* and *Vicia villosa* for grazing low yielding dairy cows during winter in small-scale dairy systems in the highlands of Mexico

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ABSTRACT

The study was undertaken to assess yield and herbage quality of two mixed short-term pastures of grass, oat, and vetch during the winter dry season for grazing low yielding dairy cows. The mixed pastures were termed as conventional (CON) and experimental (EXP) mixtures. CON was annual ryegrass (*Lolium multiflorum* cv. Westerwolds), common oat (*Avena sativa* cv. Chihuahua) and common vetch (*Vicia sativa*), and EXP was festulolium (*Lolium multiflorum* × *Festuca pratensis* cv. Spring Green), black oat (*Avena strigosa* cv. Saia), and winter vetch (*Vicia villosa* cv. Naomi). Eight low yielding Holstein cows with 462.4±43.16 kg live weight, 3.4±0.1 body condition score, milk yield of 5.1±1.7 kg/cow/day, and 135.2±88.4 days in milk were continuously grazed 4 cows/ha. A double cross-over design with 4 experimental periods was followed for animal variables. There was a significant change in net herbage accumulation on pastures between experimental periods; and no differences in animal variables. There were no significant effects in animal variables, but milk yields increased two-fold from pre-experimental yields indicating the potential of quality pastures to improve productivity in small-scale dairy systems.

Keywords: Dry season, Feeding strategies, Grazing, Herbage production, Mexico, Mixed pastures, Small-scale dairy farming

World population will increase by 25% by 2030, increasing demand for foods of animal origin. Small-scale farming systems may contribute to meet increased food needs, but many are behind in technification and development (Mwendia *et al.* 2018). In Mexico, 78% of specialized dairy farms are small-scale. They are characterized by small farm size (6–10 ha), small herds (3–35 cows in milk, plus replacement heifers), and they rely mainly on family labour. These systems contribute over 30% of national milk production, and are a rural development option providing occupation and income to farming families contributing to reduce poverty (Prospero-Bernal *et al.* 2017). The limiting factors to the productivity of small-scale dairy farms are similar around the world. They include high workloads for farmers, feed scarcity in dry seasons that creates a high dependency in external inputs that reduce their economic efficiency. In Kenya, Ghana and Mexico, there is a pronounced decrease in forage quantity and quality during the dry season, limiting the development of small-scale dairy farming (Njarui *et al.* 2017, Mwendia *et al.* 2018).

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It is possible to reduce production costs in these systems with the implementation of strategies such as intensive continuous grazing, and technologies to improve the supply of quality forages (Prospero-Bernal *et al.* 2017). Examples of these strategies are the use of silages (Burbano-Muñoz *et al.* 2018), alternative forages, and mixed pastures. Several authors agree that mixed pastures show higher yields than monocrops. The magnitude of responses depends on factors such as the individual yield of each species, the date of sowing, the adaptation to a specific area, and the seed rates at sowing (Ergon *et al.* 2016). The use of mixed pastures with legumes has many advantages, like stable yields and higher herbage quality. Mixed pastures enable the extension of herbage production through the dry season, therefore the available land can be fully utilized. They also help to improve soil fertility through nitrogen fixation; increase soil organic matter, and overall improve soil life. Mixed short-term pastures of three species have not been evaluated in central Mexico. Available evaluations are of two species grass – legume pastures or forage crops (Celis-Álvarez *et al.* 2016). Mixed short-term pastures for grazing of a small-grain cereal like oat, a legume like vetch, and a grass may

be a feeding strategy that enhances the efficiency of these systems by increasing feed supply in the dry season and reduce costs (Celis-Alvarez *et al.* 2016). The objective was to assess the performance of two mixed short-term pastures of three species under grazing by low yielding dairy cows during the dry season. A pasture from a conventional mixture of locally available seed (CON) was compared to an experimental pasture mixture from newly available grass, vetch and black oat varieties (EXP).

MATERIALS AND METHODS

The study followed an on-farm participatory livestock research approach with a participating farmer. The farm is located in the State of Mexico in the central highlands. Mean altitude is 2440 m, a sub-humid temperate climate with a mean temperature of 14°C. Mean annual rainfall is 800 mm (Burbano-Muñoz *et al.* 2018).

Short-term pasture establishment and management: An irrigated 1.5 ha plot was divided into 2 0.75 ha sections, one for each pasture mixture. Sowing rate for CON was 30 kg/ha of annual ryegrass (*Lolium multiforum* cv. Westerwolds), 60 kg/ha common vetch (*Vicia sativa*) of a local landrace, and 66 kg/ha of common oat (*Avena sativa* cv. Chihuahua). EXP seed rate was 30 kg/ha of Festulolium (*Lolium multiflorum × Festuca pratensis* cv. Spring Green); 60 kg/ha of winter vetch (*Vicia villosa* cv. Naomi), and 66 kg/ha of black oat (*Avena Strigosa* cv. Saia).

The seed was hand-sown by broadcasting on 25 November 2016, and pastures were fertilized eight days post-sowing with 58 N-30 P-0 K, and flood irrigated every four weeks.

Grazing management: Eight low yielding Holstein cows assigned in 2 groups grazed following a double cross-over design. Cows in Group 1 had a pre-experimental mean milk yield of 5.1±2.1 kg/cow/day and 149.7±133.7 days in milk. Pre-experimental yield in Group 2 was 5.3±1.8 kg/cow/day, and 120.7±32.1 days in milk. Cows were selected from the small herd of the participating farmer. Grazing started 87 days post-sowing. Experimental periods were 14 days each; 10 days for adaptation to treatment and four days for measurements (Pérez-Prieto *et al.* 2012). At the end of each period, cow groups changed to graze the other pasture in a CON-EXP-CON-EXP / EXP-CON-EXP-CON treatment sequence. Grazing system was continuous set-stocking for 9 h/day (8:00 to 17:00 h), and cows received 3.0 kg/cow/day fresh weight of a supplement made by the farmer of 80% ground maize grain and 20% soya bean meal divided in two allocations, given at milkings.

Pasture variables: Estimation of net herbage accumulation (NHA) in kg DM/ha was from 5 0.25 m^2 (0.5 × 0.5 m) exclusion cages in each pasture following. Records of compressed sward height (cm) were with a raising plate grass-metre from 25 measurements per pasture at the end of each period. Botanical composition was in the herbage cut to determine NHA; separating oat, grass, vetch and other plants.

Chemical composition of herbage: Chemical composition of herbage was determined on hand-plucked samples simulating grazing at the end of each experimental period. *In vitro* dry matter digestibility (IVDMD) and *in vitro* organic matter digestibility (IVOMD) were by incubation with ruminal liquor using the micro-bag method in a Daisy II Ankom Incubator following Ankom (2019).

Metabolizable energy content was estimated (eME) from AFRC (1993) applying equation ME = 0.0157 [DOMD] where DOMD is de digestible organic matter in the dry matter in g/kg.

Animal variables: Recording of daily milk yield (MY) during the four last days of each period was with a spring balance. Live-weight (LW) and body condition score (BCS on a 1–5 scale) were taken at the beginning of the experiment and at the end of each period after morning milking. Chemical composition of milk was from aliquot samples of morning and evening milkings in the four recording days at the end of each period, and analyzed with an ultrasound milk analyzer (Ekomilk Bond model Ultra 40s BULTEH 2000 Ltd., Bulgaria, Europe) for milk fat, protein, and lactose.

Statistical analyses: Pasture variables were analyzed with a split-plot experimental design where short-term mixed pastures (CON and EXP) were treatment fixed effects (main plots) and the 4 experimental periods were random effects (split plots), via analysis of variance with the model (Kaps and Lamberson 2004):

$$Y_{ijkl} = m + r_i + T_j + E_k + p_l + Tp_{jl} + e_{ijk}$$

A double cross-over experimental design analyzed animal variables with the treatment sequence CON-EXP-CON-EXP for Group 1 of cows, and Group 2 followed the sequence EXP-CON-EXP-CON (Tempelman 2004), randomly allotting cow group to treatment sequence. Experimental periods were 10 d for adaptation and 4 for recordings.

RESULTS AND DISCUSSION

Net herbage accumulation (NHA) and grass-metre sward height (SH): There were significant interactions (P<0.05) between treatments (short-term pasture) and experimental periods for both variables (Table 1).

NHA for CON for the experiment was 4648 kg DM/ha (83 kg DM/day) compared to 5305 kg DM/ha for EXP (94 kg DM/day). SH declined rapidly after the first grazing, but evened out thereafter. Higher NHA in the short-term pastures may have been both by the positive effects of the association as from the vigorous growth of the short-term grasses (annual ryegrass in CON and festulolium in EXP) that were major pasture components in both mixtures, combined with the high growth rates of the oat component. The plasticity of plant species with differing morphology, seasonal growth, or adaptation habits is an aspect now recognised as an advantage in multispecies pastures, which may have influenced observed results.

Observed NHA was higher than reports by Burbano-Muñoz *et al.* (2018) in the same area during the dry season with multi-species pastures of perennial ryegrass (*Lolium*

Table 1. Net herbage accumulation (NHA) and grass-metre sward height (SH)

Treatment	Experimental period				SEMMP	P value
	P1	P2	P3	P4		
NHA (kg DM/ha)						
CON	1223.3	1699.4	741.1	984.9		
EXP	2397.4	807.14	747.9	1459.5	60.96	0.666
Mean	1810.3	1253.2	744.5	1222.2		
SEMsp			440.74			0.018
SEM (MP*sp)			244.22			0.024
Sward height (cm)						
CON	26.2	11.2	13.3	16.5		
EXP	24.8	17.1	10.1	13.5	0.15	0.680
Mean	25.5	14.2	11.7	15.0		
SEMsp			5.58			0.000
SEM (MP*sp)			1.27			0.000

NHA, Net herbage accumulation; SW, Grass-metre sward height; CON, Conventional pasture mixture; EXP, Experimental pasture mixture; SEMMP, Standard error of the mean for main plots (Pastures); SEMsp, Standard error of the mean for split plots (Experimental periods); SEM (MP*sp), Standard error of the mean for the interaction of pastures × experimental periods; P value, Probability value (where $\alpha = 0.05$).

perenne) of two varieties (Bargala and Payday), festulolium (*Lolium multiflorum × Festuca pratense*) of the same Spring Green.

Significant interactions between pastures and experimental periods were observed in NHA (Fig. 1). EXP had higher NHA during P1 to decline in P2, when CON had higher NHA. Thereafter both short-term pastures had similar NHA in P3 and slightly higher for EXP in P4. This performance may indicate the advantage of both seed mixtures to ensure a stable herbage supply over the dry season.

There was no clear relationship between NHA and grass-metre compressed sward height, contrary to reports by Mwendia *et al.* (2017) evaluating 5 oat varieties in Kenya cut at 115 days after sowing. This difference could be due to them having measured total plant height, and not compressed height as in this study. The stiffer stems of the oat component surely affected the measured grass-metre sward height, while the more prostrate grasses and vetches had higher herbage mass nearer ground level.
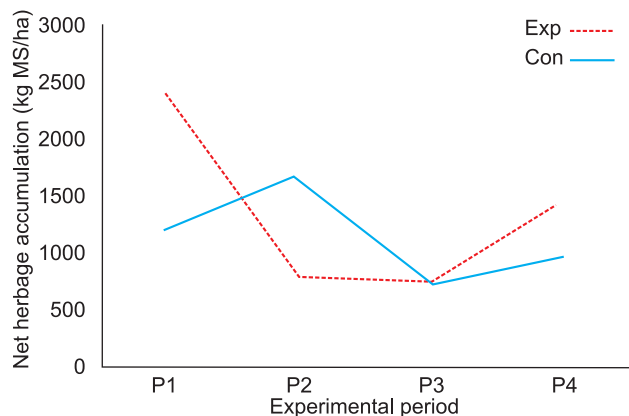

Fig. 1. Net herbage accumulation interaction between short-term pastures and experimental period.

Botanical composition: Common vetch constituted a higher proportion of DM in CON than winter vetch in EXP (P<0.05) (Table 2). Westerwolds annual ryegrass constituted significantly less (P<0.05) proportion of total DM in CON than festulolium in EXP. Festulolium represented on average just above 50% of DM in EXP.

There was a significant (P<0.05) interaction between pastures and experimental periods for the oat component. Common oat in CON declined its proportion in the DM for P2, recovering to over 40% in P3 and P4. Black oat increased in P2 to decline in P3 and P4. There were no significant differences of pastures, periods or the interaction for the proportion of other plants in the DM which were less than 10% of DM. Results indicated that festulolium was more aggressive with associated vetches and oats and that common vetch is better adapted to the agroecological conditions of the area. Both oat species have a sharp increase in their proportion after P1, with black oat increasing to 40% of DM whilst common oat did that in P3.

In spite of the vigorous growth of oats, both annual ryegrass in CON and festulolium in EXP made up an important proportion of DM. In the CON mixture, there were similar proportions of common oat (38%) and annual ryegrass (36%), whereas in the EXP mixture festulolium made up 50% of DM, black oat 30% and winter vetch only 10% of DM. Common vetch in CON represented a higher component of DM than winter vetch in EXP. This may be due to a better adaptation of the local common vetch used to the dry season and agroecological conditions, compared to the Naomi winter vetch imported from Canada that represented a mean of just over 10% of DM in EXP; so that common vetch would be a better option for these systems.

Chemical composition: Herbage from both short-term pastures was of good quality. The DM content of both pasture mixtures increased as the experiment progressed reflecting an increase in maturity which reduced *in vitro*

Table 2. Botanical composition (g/kg DM) of pastures by species and period

Treatment	Seed	P1	P2	P3	P4	Mean	SEMMP	P value
CON	CV	200.1		365.8	169.7	98.0	208.4	
EXP	WV	109.4	111.8	136.5	66.4	106.0	77.60	0.002
	Mean	154.8		238.8	153.1	82.2	157.2	
	SEMsp			52.59				0.054
	SEM (MP*sp)			27.66				0.083
CON	RG	433.9	341.4	387.8	356.2	379.8		
EXP	FL	552.8	332.4	560.8	563.9	502.5	92.01	0.005
	Mean	493.3	336.9	474.3	460.1	441.1		
	SEMsp			69.70				0.057
	SEM (MP*sp)			30.60				0.176
CON	CO	336.5	251.1	419.2	428.1	358.7		
EXP	BO	320.7	440.9	199.8	250.9	303.1	40.31	0.194
	Mean	328.6	346.0	309.5	339.5	330.9		
	SEMsp			17.12				0.913
	SEM (MP*sp)			53.35		0.020		
CON	OT	29.5	41.7	23.3	117.7	53.0		
EXP	OT	17.1	114.9	102.9	118.8	88.4	25.90	0.117
	Mean	23.3	78.3	63.1	118.2	70.7		
	SEMsp			34.73				0.104
	SEM (MP*sp)			12.89				0.398

CON, Conventional pasture mixture; EXP, Experimental pasture mixture; CV, Common vetch; WV, Winter vetch; RG, Westerwolds annual ryegrass; FL, Spring Green festulolium; CO, Chihuahua common oat; BO, Saia black oat; OT, Other plants; SEMMP, Standard error of the mean for main plots (Pastures); SEMsp, Standard error of the mean for split plots (Experimental periods); SEM (MP*sp), Standard error of the mean for the interaction of pastures × experimental periods; P value, Probability value (where α = 0.05).

digestibility and thus estimated metabolizable energy. It is probable that the oats component of pastures contributed most to declining quality given the rapid growth rates of oat species (Table 3).

In terms of chemical composition, both pastures were very similar, both with low CP content (under 120 g/kg) which might be due to the oats component in the pastures. Even in EXP where festulolium comprised just over 50% of DM, CP was low with a mean of 105 g CP/kg DM.

Herbage from both pastures was similar in chemical composition, with high energy content that decreased as the experiment progressed, but that met the metabolizable energy requirements of experimental cows with low milk yields. However, CP content was low at 100 g/kg DM, similar to reports by Flores-Nájera *et al.* (2016) for associations of common oat with common vetch.

The lower CP content in CON than EXP, remained constant for 3 experimental periods, increasing in P4. CP content in those 3 periods agrees with findings reported by Flores-Nájera *et al.* (2016) on associations of common vetch with small-grain cereals (barley, oat, and triticale). NDF and ADF content was slightly higher in P1 and P4. However, fibre content did not affect IVDMD or IVOMD with very similar eME content in both herbages; although *in vitro* digestibility values were lower than reports from Celis-Álvarez *et al.* (2016) and Burbano-Muñoz *et al.* (2018). The lower digestibility observed might be due to the lower digestibility of vetches compared with clovers as reported; but were higher than digestibilities reported by Mwendia *et al.* (2017) for winter oat forage in Kenya. Estimated ME content was higher than results from Celis-Alvarez *et al.* (2016) for perennial ryegrass – white clover with common

Table 3. Chemical composition of short-term pastures (g/kg DM except eME)

Treatment		Period				Mean
		P1	P2	P3	P4	
CON	DM	215.9	266.4	314.2	323.0	279.9
	OM	917.0	912.0	907.0	910.0	911.5
	CP	89.3	85.8	87.5	134.7	99.3
	NDF	342.2	403.2	482.0	499.9	431.9
	ADF	254.3	282.3	365.8	362.1	316.1
	IVDDM	750.3	759.2	683.3	629.9	705.7
	IVDOM	739.9	749.1	670.6	615.5	693.8
	eME (MJ/kg DM)	10.7	10.7	9.5	8.8	9.9
EXP	DM	241.3	260.6	292.8	299.4	273.5
	OM	913.0	923.0	918.0	908.0	915.5
	CP	92.8	105.1	92.8	131.2	105.0
	NDF	417.4	401.8	443.8	517.6	445.2
	ADF	302.7	280.9	360.4	405.1	337.3
	IVDDM	776.8	772.9	675.1	646.8	717.9
	IVDOM	767.3	763.3	662.2	633.0	706.5
	eME (MJ/kg DM)	11.0	11.1	9.5	9.0	10.2

CON, Conventional pasture mixture; EXP, Experimental pasture mixture; DM, Dry matter; OM, Organic matter; CP, Crude protein; NDF, Neutral detergent fibre; ADF, Acid detergent fibre; IVDDM, *In vitro* digestibility of DM; IVDOM, *In vitro* digestibility of OM; eME, Estimated metabolizable energy.

Table 4. Milk production performance as affected by type of pastures

	Treatment	P1	P2	P3	P4	SEM	P- value
Milk yield (kg/cow/day)	CON	7.63	10.01	10.94	11.01	1.38	0.890
	EXP	6.82	11.33	10.50	10.95		
Live weight (kg)	CON	404.8	428.4	424.4	435.4	16.02	0.950
	EXP	449.1	409.3	452.1	433.3		
BCS	CON	2.8	3.3	3.3	3.3	0.16	0.940
	EXP	3.1	3.3	3.3	3.1		
Milk fat (%)	CON	3.6	3.2	3.1	2.7	0.21	0.600
	EXP	3.4	3.8	3.1	2.6		
Total milk solids (%)	CON	9.5	8.4	9.1	9.3	0.20	0.990
	EXP	9.5	8.3	8.9	9.3		
Milk protein (%)	CON	3.6	3.2	3.3	3.5	0.08	0.660
	EXP	3.6	3.1	3.4	3.5		
Lactose (%)	CON	5.2	4.6	4.7	5.1	0.13	0.690
	EXP	5.2	4.5	4.8	5.1		

CON, Conventional pasture mixture; EXP, Experimental pasture mixture; BCS, Body condition score; SEM, Standard error of the mean for treatments and experimental periods; P value, probability value (where $\alpha = 0.05$).

oat herbage.

The concentrate mixed on farm had 948.0 g/kg of DM, 940.2 g OM/kg DM, a CP content of 162.8 g/kg DM, and fibre contents of 141.3 g NDF/kg DM and 20.1 g ADF/kg DM, and eME of 13.4 MJ ME/kd DM obtained from international tables of nutrients (Feedipedia 2019).

Animal performance: There were no statistical differences (P>0.05) in any of the animal variables evaluated (milk yield and composition, live weight, and body condition score; Table 4).

During the experiment, milk yield increased by a mean of 4.8 kg/cow/day. This is almost double the pre-experiment milk yield of 5.1 kg/cow/day. By the end of the experiment, mean milk yield was 2.3 times higher than the pre-experiment yield, which indicated the high quality of both the short-term pastures. This is an issue of participatory on-farm research where participating farmers get a first hand experience on how they can improve the performance of their herds.

There were no significant differences for any of the animal variables evaluated, showing both pastures proved similar for dairy production in these systems. Mean daily milk yield for the experimental cows was 9.9 kg/cow in the dry season, lower than reported by Celis-Álvarez *et al.* (2016) in the same study area, although with higher concentrate supplementation; but higher to milk yields reported by Mwnendia *et al.* (2018) from the evaluation of oat forage in Kenya.

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