Yield and quality of whole crop faba beans harvested and ensiled at different maturities

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Abstract

Faba beans can be grown over winter as a cover crop to reduce nitrogen (N) leaching and produce a protein feed when harvested as a whole crop in spring. In this study, faba beans were sown in the Waikato in three consecutive years (2016-2018) and harvested in spring at 2-week intervals to measure yield, feed value and silage characteristics. Yield averaged 7.1 t DM/ha in the third week of November after 23 to 28 weeks of winter/spring growth. The yield range was 5.9 to 8.8 t DM/ha in the 3 years. Feed quality declined gradually with maturation. In the third week of November metabolisable energy (ME) was low at 8.0 MJ/kg DM and crude protein (CP) was 14.5 %DM when averaged over 3 years. Results from earlier harvests showed higher feed value (ME and CP) but there was a compromise with lower yield. Indicators of fermentation quality (pH, Ammonia-N%Total N and organic acid profile) showed that whole crop faba beans could be made into acceptable quality silage if harvested in late October to early November and wilted to 30-40% DM before ensiling.

Additional keywords: *Vicia faba*, cover crop, feed quality, silage quality

Introduction

Faba beans (*Vicia faba* L.) are an annual leguminous species well suited for short crop rotations when harvested as ensiled forage (Borreani *et al*. 2009). This is a low-cost option for farm-grown protein feed that can substitute for other protein concentrates in dairy farm systems. As a winter active species, faba beans provide a cover crop option to reduce winter and spring nitrate leaching in the Waikato (Zyskowski *et al*. 2016), and could act as a catch crop to mop excess nitrogen (N) in late winter and spring contributing to environmentally friendly farming practices. Overseas research has shown that whole crop faba beans grown over winter yielded 7.1 t DM/ha over 29 weeks in Northern Italy (Borreani *et al*. 2009), and yields from South Africa were similar at 7.1 and 9.0 t DM/ha in 24 and 23 weeks (Louw 2009).

A FAR publication has highlighted aspects of faba bean production under New Zealand conditions and presented guidelines for growers around the management of the crop (FAR 2012). There is incomplete information on best harvest times and methods for conserving whole crop faba beans in New Zealand environmental conditions. The present study examined the effect of harvest maturity on silage quality of whole faba beans, to better define harvest dates to achieve best productivity and quality.

Materials and Methods

Experimental details

Faba bean trials were established at the FAR Northern Crop Research site at Tamahere located in the Waikato, New Zealand (37.84° S, 175.37° E) on a Horotiu sandy loam.

Faba beans (cultivar 'Ben') were grown in three consecutive years (2016-2018) in four adjacent blocks that were previously in maize for grain. Each block was 6 x 50 m. Within each block a randomly selected plot was manually harvested as whole plants using a 1x1m frame at 2-week intervals. Sowing dates and harvest dates differed between years (Table 1) and therefore the periods of active growth differed for each season. Sampling occurred between weeks 28–34 in Year 1, weeks 21–27 in Year 2 and weeks 21–29 weeks in Year 3.

Table 1: Sowing and harvest dates of whole faba beans in three different years at the FAR Northern Crop Research Site at Tamahere, Waikato.

Year	2016	2017	2018
Sow date	10 May	12 June	18 May
Harvest date (weeks grown)			12 Oct (21)
			26 Oct (23)
		8 Nov (21)	9 Nov (25)
	23 Nov (28)	22 Nov (23)	23 Nov (27)
	5 Dec (30)	6 Dec (25)	7 Dec (29)
	22 Dec (32)	20 Dec (27)	
	4 Jan (34)		

The winter/spring growing season during 2016 was similar to the 30-year average temperatures, but rainfall was higher in September/October and slightly lower in December. The 2017 winter/spring was characterised by a warmer than average spring, a notably wetter winter and a drier December. In 2018 winter temperatures were typical for the area but spring temperatures were higher than normal. Rainfall was below average in early spring and much higher in December (Figure 1).

Measurements

At each harvest plant material was sampled, weighed and dried at 60°C to constant weight for % dry matter (DM) determination. For quality assessment plant material was wilted under cover for 1-2 days aiming to raise the %DM to 30–40% as recommended for ensiling. Plant material was processed with a garden shredder to maximum of 3 cm chop length, and a representative sample saved for feed value (DM%, soluble sugars, ash, crude protein, starch, NDF, ADF and ME) by Hill Laboratories. Three additional representative samples were vacuum packed within hours of processing. Vacuum packaging has been shown to provide near perfect ensiling conditions (Hoedtke & Zeyner 2011). Each vacuum package contained a minimum of 500 g fresh material and was regularly checked for an airtight seal. Ensiled samples were opened after a minimum of 60 days storage and sent to Hill Laboratories for quality and fermentation indicators (pH, Ammonia-N % Total N, organic acids).

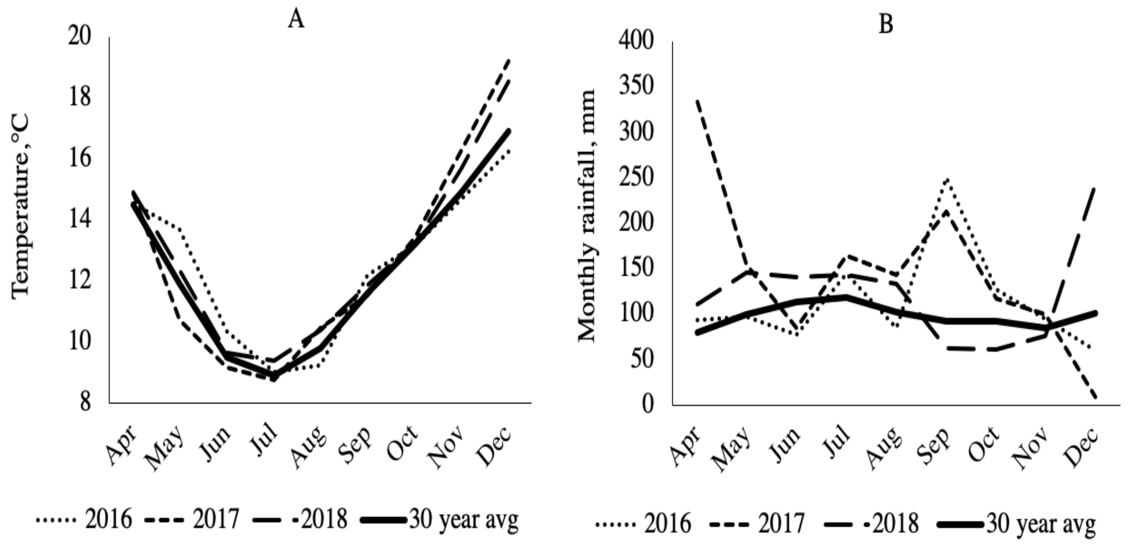

Figure 1: Average monthly temperature (**A**) and rainfall (**B**) over three growing seasons. Data was from FAR weather station at the Northern Crop Research site at Tamahere, Waikato.

Statistical analysis

Statistical analysis was performed for yield within each year using a randomised block analysis of variance (ANOVA) with block as the blocking factor and sample date as the treatment factor. This “within year” analysis was not possible for other variables since plots were then bulked within each treatment, so only one (bulked mean) value per treatment was available for each date within each year. However, for these variables it was possible to validly combine data over the years as follows. To combine these mean data for each variable for harvested material across the 3 years a randomised block ANOVA was used, with the 3 years treated as the blocking factor and four dates (dates 3 – 6) treated as the treatment factor, with two data points being treated as “missing values” (these were date 3 in 2016 and date 6 in 2018). To combine the mean silage data across the 2 years (2016 and 2017) in which they were available a randomised block ANOVA was used, with the 2 years treated as the blocking factor and four dates (dates 1 – 4) treated as the treatment factor, with one data point being treated as a “missing value” (date 1 in 2016). In all cases date means were then compared using an unrestricted least significant difference (LSD) procedure (Saville 2015).

Results and Discussion

Yield

Dry matter yield differed between the 3 years (Figure 2). In the first year (2016) whole crop faba beans produced a mean of 8.7 t DM/ha; and in the following year 5.5 t DM/ha. This was explained by a 7-week shorter growing period in 2017 than in 2016 because of delayed planting. Across 3 years the rate of growth appeared to decline after an initial rapid growth phase. In 2018 sampling for yield and quality was initiated at earlier growth stage to capture any potential quality gains from harvesting younger material. Final harvest was 4 weeks earlier than in 2016, and 2 weeks earlier than in 2017.

While the initial growth pattern is explained by the different planting dates, the differences in yield could also be related to temperature and rainfall patterns experienced during the early growth phases. In September and October there was little difference in temperature pattern, but rainfall was higher in these months for the first 2 years (Figure 1B). It is probably of little relevance that yield attained in year 1 was highest when average monthly temperature (Figure 1A) was lowest in the November – December period, and yield was lowest when the mean monthly temperature November – December was highest. The crop with the lowest yield (in 2017) was planted 5 weeks later than season 1 but received less rainfall in December. Grain legumes are generally responsive to the growing environment and especially show strong annual variation (Wichmann *et al.* 2005). Winter grown whole faba beans in Northern Italy produced 7.1 t DM/ha over 29 weeks of growth (Borreani *et al*. 2009), and yields from South Africa were at 7.1 and 9.0 t DM/ha after 24 and 23 weeks, with the lower yield linked to lower rainfall (Louw 2009).

Plant composition at harvest

Whole crop faba beans changed its composition during maturation. The change in moisture content accompanied the shift in feed value indicators with the biggest change occurring in December. Pre-ensiling quality was determined until crop maturity in 2016 and 2017 but was not taken for the late December harvest in 2018. Starch increased significantly (P<0.05) from late November onwards and soluble sugars and crude protein percentage decreased numerically later in December. Fraser *et al.* (2001) demonstrated how spring grown faba bean development during 10-14 weeks of maturity is characterised by a significant decrease of leaf, containing fibre and protein, and a similar increase of pod material containing starch as a proportion of DM yield during later stages of maturation.

Overall results from this trial indicate that yield reached a maximum in late November accompanied by low–medium feed quality of 8.0 MJ ME/kg DM, 1.5% starch and 14.5% crude protein. A longer growth period did not significantly increase yield and only numerically improved ME to 8.7 MJ/kg DM, however there is a growing risk of sudden dry down from late November and there is less opportunity to grow a summer crop after the faba bean harvest. An earlier harvest e.g. 8/9th November, meant a 30% lower (P<0.05) yield but a higher (P<0.05) protein content of up to 17.3% DM. Some growers may choose to harvest earlier and sacrifice yield to improve feed value (ME and crude protein) and enable

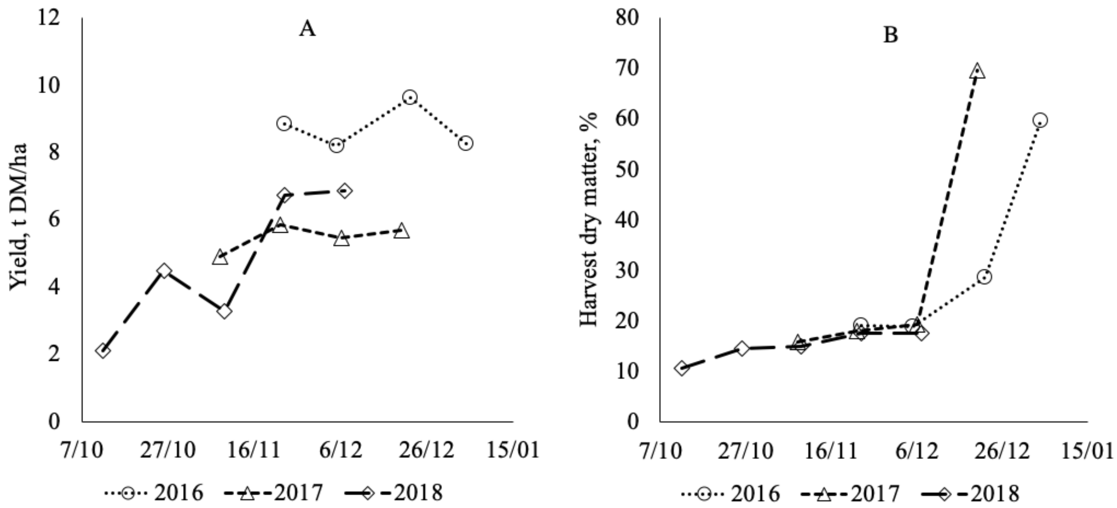

Figure 2: Yield (**A**) and harvest dry matter % (**B**) of whole crop faba beans harvested in three respective seasons (2016, 2017 and 2018) at FAR Northern Crop Research site at Tamahere, Waikato.

establishment of a summer crop e.g. maize, earlier in spring following the faba bean harvest.

Ensiled crop quality

The ensiling characteristics of whole crop faba beans was investigated in two seasons only (2016 and 2017). Crop was harvested at less than 20% DM before the first week of December therefore too wet for ensiling without wilting (Table 2). When harvested at advanced maturity (late December in both years) there were opportunities for direct chopping and ensiling without wilting. The target ensiling DM of 30–40% was nearly achieved at all harvesting dates when harvested faba bean material was wilted for 2 days (Table 3), however in both years the DM% increased quickly in December and was too dry in the standing crop. At early and medium maturities the soluble sugar levels were adequate (at 8.2 - 10.6% of DM) for conversion to organic acids during ensiling. By late December soluble sugars decreased to 5.5 %DM (P<0.05). A target of 30–40%DM and adequate sugar levels are desired factors for good silage fermentation.

A comparison of the whole crop faba bean quality in this trial with values typical of well fermented crops (Kleinmans 2016) indicated that faba beans have good potential if wilted. Quality estimates were also consistent with overseas recommendations for well-made legume silages (Kung & Shaver 2001). A minimum pH of 4.3–4.7 is recommended for legume silages at 30–40% DM; or a pH of 4.7-5.0 for higher DM% (45-55%) legume silage. Ammonia-N %Total N indicates the extent of protein degradation during fermentation. Levels below 10% are recommended and were well achieved here (Table 3). High lactic acid is indicative of a desirable fermentation. A high level of lactic acid (7–8% with 30–40% DM and 2–5% with high DM silage) and low levels of acetic acid (2–3% with 30–40% DM and 0.5–2% with high DM silage) are desired (Kung & Shaver 2001). The silage organic acid profile of faba bean silage (Table 3) was adequate without any butyric or propionic acid found (data not shown) and reflected medium to good quality. Drier and later maturity crops were lower in soluble sugar

Table 2: Yield and quality of whole crop faba beans grown over winter in 3 years and harvested at different times at the FAR Northern Crop Research Site at Tamahere, Waikato.

Harvest dates	2016	-	-	-	23/11	5/12	22/12	4/01	**LSD (5%)**
	2017	-	-	8/11	22/11	6/12	20/12	-	
	2018	12/10	26/10	9/11	23/11	7/12	-	-	
Yield t DM/ha	2016	-	-	-	8.83^{ab}	8.17^{b}	9.62^{a}	8.25^{ab}	*1.38*†
	2017	-	-	4.90^{a}	5.86^{a}	5.46^{a}	5.68^{a}	-	*1.98*
	2018	2.09^{c}	4.48^{b}	3.28^{bc}	6.73^{a}	6.86^{a}	-	-	*1.42*
	Mean	**-**	**-**	**4.98^{b}**	**7.14^{a}**	**6.83^{ab}**	**7.30^{a}**	**-**	**2.13**
Pre-wilted % DM	2016	-	-	-	19.20	18.90	28.60	59.70	
	2017	-	-	15.85	17.98	19.23	69.60	-	
	2018	10.60	14.60	15.00	17.60	17.60	-	-	
	Mean	**-**	**-**	**12.19^{b}**	**18.26^{b}**	**18.58^{b}**	**49.29^{a}**	**-**	**27.54**
Crude Protein %DM	2016	-	-	-	11.95	12.25	11.50	9.50	
	2017	-	-	18.15	15.00	16.70	12.65	-	
	2018	24.55	20.00	18.55	16.60	15.50	-	-	
	Mean	**-**	**-**	**17.29^{a}**	**14.52^{b}**	**14.82^{b}**	**12.75^{b}**		**2.33**
Starch %DM	2016	-	-	-	0.00	3.95	11.10	5.90	
	2017	-	-	0.00	1.55	8.55	9.90	-	
	2018	2.90	0.00	0.65	3.00	8.25	-	-	
	Mean	**-**	**-**	**0^{c}**	**1.52^{c}**	**6.92^{b}**	**11.15^{a}**	**-**	**3.32**
Soluble Sugars %DM	2016	-	-	-	12.25	6.75	4.95	1.20	
	2017	-	-	9.15	5.45	6.40	3.45	-	
	2018	16.50	19.85	11.55	14.15	11.45	-	-	
	Mean	**-**	**-**	**10.28^{ab}**	**10.62^{a}**	**8.20^{ab}**	**5.54^{b}**	**-**	**4.77**
ME MJ/kg DM	2016	-	-	-	7.80	8.15	8.35	6.50	
	2017	-	-	7.95	6.90	9.15	8.25	-	
	2018	10.50	10.05	8.70	9.15	9.05	-	-	
	Mean	**-**	**-**	**8.15^{a}**	**7.95^{a}**	**8.78^{a}**	**8.64^{a}**	**-**	**1.44**

*Analysis of variance was performed with 4 dates ("treatments") and 3 years ("blocks"). The "missing value" technique was used to adjust for the fact that early and late harvest samples were missing from the respective 2016 and 2018 seasons. Letters within rows have been assigned on the basis of the 5% unrestricted LSD procedure (Saville 2015); date means with no letters in common differ significantly at $P<0.05$.

†LSD (5%) values in italics are from an analysis of variance within that year.

Table 3: Silage quality of whole crop faba beans grown over winter in 3 years and harvested at different times at the FAR Northern Crop Research Site at Tamahere, Waikato.

Harvest dates	2016	-	23/11	5/12	22/12	4/01	**LSD (5%)**
	2017	8/11	22/11	6/12	20/12	-	
Silage DM%	2016	-	27.20	32.70	57.50	77.70	
	2017	26.10	31.70	35.50	67.30	-	
	Mean	**23.25**^{b}	**29.45**^{b}	**34.10**^{b}	**62.40**^{a}	-	**11.11**
pH	2016	-	3.90	4.00	4.40	5.90	
	2017	4.10	4.10	4.10	5.27	-	
	Mean	**3.91**^{a}	**4.00**^{a}	**4.05**^{a}	**4.83**^{a}	-	**1.27**
Ammonia-N %TN	2016	-	7.60	7.90	5.87	1.93	
	2017	8.37	6.60	7.90	3.37	-	
	Mean	**8.95**^{a}	**7.10**^{ab}	**7.90**^{ab}	**4.62**^{b}	-	**3.83**
Lactic Acid %DM	2016	-	5.97	4.57	2.33	0.00	
	2017	7.20	6.23	5.37	0.80	-	
	Mean	**7.28**^{a}	**6.10**^{a}	**4.97**^{ab}	**1.57**^{b}	-	**3.71**
Acetic Acid %DM	2016	-	1.67	0.87	0.47	0.00	
	2017	1.87	1.13	1.10	0.23	-	
	Mean	**1.96**^{a}	**1.40**^{ab}	**0.99**^{ab}	**0.35**^{b}	-	**1.18**

*Analysis of variance was performed with 4 dates (“treatments”) and 2 years (“blocks”), with one "missing value" declared (the earliest date sample in 2016).
Letters within rows have been assigned on the basis of the 5% unrestricted LSD procedure (Saville 2015); date means with no letters in common differ significantly at $P<0.05$.

levels and produced less lactic acid. Very high DM% material e.g. silage DM of 67.3% and 77.7% when harvested in late December, produced very low lactic acid (0.8% and 0.0%) and high pH (5.27 and 5.90). This is typical of low moisture material that is prone to low stability and aerobic deterioration on opening. In addition, high DM silages are difficult to compress and oxidative deterioration is more likely due to trapped air.

Conclusions

The main conclusions from this trial are:

1. Whole crop faba beans produced a mean yield of 7.1 t DM/ha by late November 23–28 weeks after sowing in the Waikato. The range in yield over seasons was 5.9–8.8 t DM/ha with differences due to planting date and seasonal effects.

2. Feed quality of whole crop faba beans declined gradually. In late November, metabolisable energy was low (8 MJ/kg DM) and crude protein at 14.5% DM. By harvesting earlier (late October or early November) the feed value was higher but yield was lower.

3. Whole crop faba beans ensile well but they require wilting if cut before mid-December. Dry down occurs rapidly in December, and if ensiled at high DM content the quality is compromised through restricted fermentation and potential aerobic deterioration.

4. Growers may choose a compromise between yield and quality by selecting early vs later harvest. Earlier harvest allows for timely planting of a following summer crop but the crop will require wilting before ensiling. Later harvest may allow a direct chop harvest but the quality is lower.

Acknowledgements

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References

Borreani, G.; Chion, A.R.; Colombini, S.; Odoardi, M.; Paoletti, R.; Tabacco, E. 2009. Fermentative profiles of field pea (*Pisum sativum*), faba bean (*Vicia faba*) and white lupin (*Lupinus albus*) silages as affected by wilting and inoculation. *Animal Feed Science and Technology 151*: 316-323.

FAR, 2012. Faba beans - a grower's guide. https://www.far.org.nz/assets/files/uploads/26313_FAR_focus_8_-_faba_beans.pdf (accessed 29.5.19).

Fraser, M.D.; Fychan, R.; Jones, R. 2001. The effect of harvest date and inoculation on the yield, fermentation characteristics and feeding value of forage pea and field bean silages. *Grass and Forage Science 56*: 218-230.

Hoedtke, S.; Zeyner, A. 2011. Comparative evaluation of laboratory-scale silages using standard glass jar silages or vacuum-packed model silages. *Journal of the Science of Food and Agriculture 91*: 841-849.

Kleinmans, J. 2016. A review of silage inoculants in the New Zealand market. https://www.far.org.nz/assets/files/blog/files//4e572e32-9505-491a-a015-60ad071e22f9.pdf (accessed 29.5.19).

Kung, L.; Shaver, R. 2001. Interpretation and use of silage fermentation analysis reports. Focus on forage 3, 1–5. https://fyi.extension.wisc.edu/forage/files/2014/01/Fermentation.pdf (accessed 29/5/19).

Louw, A.W. 2009. The nutritive value of faba bean silage for lactating dairy cows (Masters Thesis). Stellenbosch University, Stellenbosch South Africa.

Saville, D.J. 2015. Multiple Comparison Procedures—Cutting the Gordian Knot. *Agronomy Journal 107*: 730-735.

Wichmann, S.; Loges, R.; Taube, F. 2005. Ertragsbildung und Qualitätsentwicklung von Körnerleguminosen zur Ganzpflanzennutzung in Reinsaat und im Gemenge mit Getreide. *Pflanzenbauwissenschaften 9*: 61-74.

Zyskowski, R.F.; Teixeira, E.I.; Malcolm, B.J.; Johnstone, P.R.; de Ruiter, J.M. 2016. Effectiveness of winter cover crops to reduce nitrogen leaching losses in cropping systems in Waikato, New Zealand. *Agronomy New Zealand 46*: 109-119.