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Effect of Sowing Rate and Maturity on the Yield and Nutritive Value of Triticale–Field Pea Forage Crops

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Abstract: Experiments were conducted over three years at Murrumburrah, in southern NSW, Australia to assess the yield and nutritive value of triticale–pea forage crops. Field pea (*Pisum sativum* L. cvv. Parafield and Morgan) were sown at 40 or 80 kg ha^{-1} in mixtures with triticale (x *Triticosecale* Wittmack cv. Tobruk) at 15, 30 or 45 kg ha^{-1} and sampled when the triticale was at the boot, anthesis, and milk stage of maturity, though lodging forced the third harvest at Murrumburrah to be abandoned. The yield, botanical composition, and forage nutritive value was determined. The yield was dependent on seasonal rainfall conditions ranging from an average of 58,326 kg ha^{-1} dry matter (DM) in 2009 to 19,914 kg ha^{-1} in 2010. The pea content was higher in Morgan compared to Parafield crops (486.4 vs. 384.8 g kg^{-1}), and those sown at 80 kg ha^{-1} compared to 40 kg ha^{-1} (485.3 vs. 385.8 g kg^{-1}). The crude protein (CP) content was higher when pea were sown at 80 kg ha^{-1} compared to 40 kg ha^{-1} (124.9 vs. 114.4 g kg^{-1} DM). Digestibility declined from 704.3 to 639.9 g kg^{-1} between the boot and milk harvests. Some yield, digestibility, and crude protein differences occurred due to pea variety, or due to triticale or pea sowing rates; however, these were infrequent, and the effect was minor.

Keywords: triticale; pea; forage; digestibility; crude protein; forage conservation

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Citation: Piltz, J.W.; Rodham, C.A. Effect of Sowing Rate and Maturity on the Yield and Nutritive Value of Triticale–Field Pea Forage Crops. *Sustainability* **2022**, *14*, 3637. https://doi.org/10.3390/su14063637

Academic Editors: Athanasios Ragkos and Alexandros Theodoridis

Received: 28 February 2022
Accepted: 16 March 2022
Published: 19 March 2022

1. Introduction

The world's human population is predicted to reach 9.15 billion people by 2050, with demand for ruminant livestock products estimated to increase by between 1.4 and 1.8 the times 2010 consumption levels during this period [1]. Meeting this demand will require additional feed resources, principally high quality forage, to overcome livestock production constraints caused by periods of deficit in both forage availability and/or forage quality [2–5]. Countries such as Australia, which is a major exporter of beef and sheepmeat, will seek to adapt their farming systems to sustainably increase production to meet this increased demand. These future ruminant livestock production systems will be shaped by world demand, seasonality of forage production, and the impacts of climate change.

In southern Australia, peak crop and pasture growth occur during the spring when both temperature and available soil moisture are favorable, with deficits in quality and availability occurring in summer and winter, respectively [6,7]. Climate change is predicted to exacerbate deficiencies in forage availability as seasons become drier and rainfall more variable [4,7]. Conservation of surplus pasture or specially grown crops as hay or silage is a management strategy that can be used to fill seasonal feed gaps and increase production [8]. In addition, conserved forage can be used to minimize risk, manage climate change, reduce the impact of floods and drought, and maintain productive capacity of the breeding herd from year to year through access to an additional source of stored fodder.

Production systems that use conserved forage can be used to redistribute forage grown across a year and to remove grazing pressure on pasture during periods of low availability. Consequently, removing the risk of overgrazing can lead to adverse effects on soil and other plant species, particularly under adverse climatic events, such as drought. A well-managed forage conservation program will utilize plant species that most appropriately match climatic and soil physicochemical constraints and also maintain or improve the natural resource base [7]. These species will require attributes of adaptation to variable climatic conditions with capacity to produce harvestable quantities of material of high nutritive value to optimize livestock production, even under moisture-constrained conditions.

Cereals (wheat, barley, triticale, oats) are ideally suited to southern Australia, producing good yields of forage for conservation under a range of seasonal conditions [9,10]. However, cereal crops often have low to moderate protein levels when conserved, making them less than ideal for highly productive livestock, including dairy cows, young growing sheep, and cattle [10–13]. Legumes such as field pea (*Pisum sativum* L.) and vetch (*Vicia* spp.) have higher protein and digestibility but can be lower yielding and require physical support to prevent lodging [14]. Growing cereals in mixtures with one of these legumes is an option to increase yield, reduce lodging, and produce forage with adequate energy and protein levels [15–17]. Growing legumes in mixtures with cereals also removes the need to supply fertilizer nitrogen (N) to the crop [18].

Several authors have reported the benefits of cereal–legume forage crops, such as those indicated previously. This has included studies from a number of countries and regions including the United Kingdom, Europe, North America, and Western Asia [18–21]. The locations include a diversity of soil types, cereal and legume species and varieties, rainfall (and irrigation), and fertilizer, as well as a range of measured crop yield and quality attributes. The diversity in yield and quality highlights the need for regional research and helps to identify the best combinations for local conditions. Furthermore, while some studies reported the effect of varying the ratio of legume to cereal seed at sowing on yield and quality for vetch, pea, wheat, barley, oat, and triticale combinations [18,19,22–24], those specifically comparing triticale to pea ratios are much less [25]. These studies did not examine the effect of varying the cereal and legume component sowing rates independently of each other, and most were restricted to only one or two harvest times, i.e., stages of plant maturity.

In Australia, there are limited data on the management of cereal–legume mixtures for hay and silage production. Thus, there are questions around what the optimum sowing rates, harvest times, preferred species, types, and varieties are [13]. This paper reports on the agronomic and feed quality attributes of triticale–pea forages grown to test the hypotheses that (1) a higher pea–triticale content leads to increased forage feed value; (2) forage quality declines with increasing plant maturity; and, (3) forage type field peas have higher quality than a semi-leafless variety.

2. Materials and Methods

2.1. Weather Data

Forage crops containing one of two field pea cultivars were sown in mixtures with triticale (x *Triticosecale* Wittmack) in plot experiments at Murrumburrah, New South Wales, Australia in 2009, 2010, and 2011. Rainfall data for Murrumburrah (34°55′ S, 148°37′ E) were obtained from the Australian Bureau of Meteorology website (http://www.bom.gov.au/climate/data/: accessed on 17 June 2021). Annual rainfall and rainfall during the growing season from April to November were both below average in 2009 and above average in 2010. In 2011, annual rainfall was above average but growing season rainfall was below average (Table 1).

Table 1. Annual and growing season rainfall (mm) at Murrumburrah, NSW compared to the long-term average (average).

Year	Annual Rainfall		Growing Season Rainfall [1]	
	Experiment	Average	Experiment	Average
2009	457.6	608.5	203.2	317.8
2010	1042.8		357.8	
2011	715.2		221.8	

[1] Rainfall from April to November inclusive.

2.2. Crop Production

Field pea cvv. Parafield and Morgan were sown at either 40 or 80 kg ha^{-1} in mixtures with triticale cv. Tobruk at 15, 30, or 45 kg ha^{-1}, hereafter referred to as P40, P80, T15, T30, and T45, respectively. Parafield is a leafy forage type and Morgan a semi-leafless type pea variety. In comparison, traditional sowing rates for triticale and field pea monocultures in that locality are 60–100 kg ha^{-1} and 70–90 kg ha^{-1}, respectively [26]. Plots were sown with a cone seeder (Agrowplow, Soil Care Systems International Pty Ltd., Molong, Australia) with both species seeds in the same row. Each plot was 1.5 m wide (9 rows with 17 cm row spacing) and 9.1 m long with 3 replicates per treatment. Monoammonium phosphate (MAP) fertilizer (10% N; 21.9% P) at 105 kg ha^{-1} was applied at the time of sowing. Sowing occurred on 25 May 2009, 28 May 2010, and 2 June 2011. Plots were sown in a randomized plot design, with a cereal crop buffer to prevent edge effects. Crops were harvested at the boot, flowering, and milk stages, equivalent to approximate growth stage (GS) 45, 65, and 75 of triticale maturity [27], hereafter referred to as H1, H2, and H3. In 2009, moisture stress (drought) caused early plant deaths, particularly of the pea component, and the H3 harvest was abandoned. Harvests occurred on 12 and 29 October in 2009; 18 October and 4 and 22 November in 2010; and 14 and 28 October and 11 November in 2011.

2.3. Crop Harvesting

In 2009, the plots were harvested using a 1.15 m-wide Allan scythe to cut through the width of each plot. In 2010 and 2011, where yields were higher, a section which was 4 rows wide × 50 cm long was cut from each plot. The cutting height was approximately 5 cm above ground level for all harvests to mimic the cutting height of commercial scale mowers. A subsample from each plot was chopped at the time of harvest using a Morrison® garden mulcher (Morrison Industries, Hastings, New Zealand) and dried overnight in a fan-forced oven at 80 °C to determine the DM content and yield; this sample was subsequently ground through a 1 mm screen for laboratory analyses using a Perten® 3100 laboratory mill (PerkinElmer Inc., Waltham, MA, USA). A second subsample was retained for botanical separation to determine the proportion of cereal to pea on a dry matter basis.

2.4. Sample Processing and Chemical Analysis

The ground samples were analyzed for digestibility using the Tilley and Terry rumen fluid method [28], modified to provide additional nitrogen (N) [29], and using a Daisy II® incubator (ANKOM Technology, Macedon, NY, USA). Organic matter (OM) was determined by heating in a muffle furnace at 550 °C for six hours. Digestibility results are reported as predicted in vivo organic matter digestibility (DM basis) (DOMD). The content of water-soluble carbohydrates (WSC) was determined using the alkaline ferricyanide method and nitrogen (N) content was determined using the Dumas combustion method, and the crude protein (CP) content was calculated as N × 6.25 [30]. Acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined by near-infrared reflectance (NIR) with a Bruker multi-purpose analyzer (MPA, Bruker Optik GmbH, Ettlingen, Germany) and OPUS software (version 5.1) with calibrations developed by the NSW Department of Primary Industries' NSW Feed Quality Service using the NDF and ADF methods, and sequentially analyzed using the filter bag method (Ankom® 200/220 fiber analyzer, ANKOM technology, Macedon, NY, USA) [31].

2.5. Stastical Analysis

Data were analyzed using the REML function in Genstat (ver 20.1) with year, triticale sowing rate, pea sowing rate, pea variety, harvest, and all interactions as fixed effects, and both replicate and plot within year as random effects [32]. All higher and second-order interactions were shown to be statistically non-significant or biologically unimportant and subsequently dropped from the analyses. Similarly, the effect of year and its interactions on relationships between forage quality parameters was shown to be statistically non-significant or biologically unimportant. Therefore, the contents of DOMD, CP, WSC, ADF, and NDF were subsequently analyzed with triticale sowing rate, pea sowing rate, pea variety, harvest, and all first-order interactions as fixed effects, and year, replicate within year, and plot within year as random effects. REML is a method used to fit linear mixed models using the restricted maximum likelihood approach. Comparisons were made using the l.s.d. calculated as the s.e.d. provided by the Genstat output multiplied by the appropriate *t* value for that number of observations.

3. Results

The yield varied between years ($p < 0.05$) such that 2010 > 2011 > 2009 for all triticale and pea sowing rates and individual harvests, consistent with differences in rainfall received. There were interactions between year and triticale sowing rate ($p = 0.031$), year and pea sowing rate ($p = 0.007$), and year and harvest ($p < 0.001$) (Table 2). The yield was higher ($p < 0.05$) for T15 compared to T30 and T45, and for P80 compared to P40 in 2010. The yield increased ($p < 0.05$) with successive harvests (triticale maturity) in each year except between H2 and H3 in 2011. The interaction between the triticale and pea sowing rate ($p = 0.019$) was also significant. The yields were higher ($p < 0.05$) for P80 compared to P40 at T15 (14,659 vs. 13,120 kg DM/ha) and T30 (14,833 vs. 12,992 kg DM/ha) but not T45 (13,900 vs. 14,030 kg DM/ha).

Table 2. The effect of year and triticale sowing rate, pea sowing rate, and stage of triticale maturity at harvest on the yield of triticale–pea forage crops grown at Murrumburrah, NSW.

Year	Triticale Sowing Rate (kg ha^{-1})			Pea Sowing Rate (kg ha^{-1})		Triticale Maturity at Harvest		
	15	30	45	40	80	Boot	Flower	Milk
2009	5233 ^{a}	6047 ^{a}	6198 ^{a}	5868 ^{a}	5784 ^{a}	4483 ^{a}	7169 ^{b}	-
2010	20,712 ^{d}	19,457 ^{c}	19,575 ^{c}	18,786 ^{c}	21,044 ^{d}	11,863 ^{d}	19,740 ^{e}	28,142 ^{f}
2011	10,566 ^{b}	11,527 ^{b}	11,414 ^{b}	10,781 ^{b}	11,557 ^{b}	8749 ^{c}	12,006 ^{d}	12,752 ^{d}
p value		0.031		0.007			<0.001	
l.s.d.$_{(p < 0.005)}$		1104.0		887.2			1266.0	

Values within year by triticale sowing rate, year by pea sowing rate, and year by triticale maturity combination with different superscript letters(a, b, c, d, e, f) are different ($p < 0.05$).

The crop dry matter content varied due to the interaction between the triticale sowing rate, harvest, and year ($p = 0.005$) (Table 3). The dry matter content at the boot stage was lower ($p < 0.05$) in 2009 and 2010 compared to 2011, and similar to the flower stage harvest in 2010. The dry matter content increased ($p < 0.05$) with successive harvests and varied ($p < 0.05$) with the triticale sowing rate at the final harvest in all years.

The crop pea content varied with the interaction between year and pea variety ($p = 0.003$), as the pea content was higher ($p < 0.05$) for Morgan than Parafield in 2009 and 2011, while the proportion of pea in the Parafield crops was higher ($p < 0.05$) in 2010 compared to 2009 and 2011 (Table 4).

Table 3. The effect of the triticale sowing rate (kg ha^{-1}) and the stage of triticale maturity at harvest on the dry matter content (g kg^{-1}) of triticale–pea forage crops grown at Murrumburrah, NSW over 3 consecutive years.

Triticale Sowing Rate	2009			2010			2011		
	Boot	Flower	Milk	Boot	Flower	Milk	Boot	Flower	Milk
15	157.8 ^{a}	308.6 ^{de}	-	165.0 ^{a}	210.0 ^{b}	327.9 ^{f}	212.8 ^{b}	280.1 ^{c}	381.9 ^{i}
30	173.8 ^{a}	329.7 ^{fg}	-	166.2 ^{a}	216.2 ^{b}	346.4 ^{gh}	221.3 ^{b}	292.0 ^{cd}	395.8 ^{i}
45	164.3 ^{a}	358.9 ^{h}	-	170.7 ^{a}	216.9 ^{b}	325.4 ^{ef}	216.9 ^{b}	296.5 ^{cd}	415.4 ^{j}
p value					0.005				
l.s.d$_{(p < 0.005)}$					18.41				

Values within pea variety × pea sowing rate and pea variety × triticale maturity combination with different superscript letters(a, b, c, d, e, f, g, h, i, j) are different ($p < 0.05$).

Table 4. The effect of year and pea variety on the pea content (g kg^{-1}) of triticale–pea forage crops grown at Murrumburrah, NSW.

Year	Pea Variety	
	Morgan	Parafield
2009	518.7 ^{b}	334.0 ^{a}
2010	479.4 ^{b}	474.6 ^{b}
2011	461.1 ^{b}	345.9 ^{a}
p value	0.003	
l.s.d$_{(p < 0.005)}$	94.48	

Values on with different superscript letters (a, b) are different ($p < 0.05$).

The pea content also varied with triticale by the pea sowing rate interaction ($p = 0.044$). The pea content was highest ($p < 0.05$) at T15-P80 and higher ($p < 0.05$) for P80 than P40 in combination with T15 and T30 but not T45 (Table 5). The pea content declined ($p < 0.05$) as the triticale sowing rate increased so that T15 > T30 and T45 at P40 and T15 > T30 > T45 at P80.

Table 5. The effect of triticale and pea sowing rate on the pea content (g kg^{-1}) of triticale–pea forage crops grown at Murrumburrah, NSW.

Triticale Sowing Rate (kg ha^{-1})	Pea Sowing Rate (kg ha^{-1})	
	40	80
15	462.6 ^{b}	601.6 ^{c}
30	349.9 ^{a}	473.5 ^{b}
45	344.9 ^{a}	381.2 ^{a}
p value	0.044	
l.s.d$_{(p < 0.005)}$	70.74	

Values with different superscript letters (a, b, c) are different ($p < 0.05$).

The crop digestibility varied with interactions between pea variety and pea sowing rate ($p = 0.038$), and pea variety and triticale maturity at harvest ($p = 0.038$) (Table 6). The crops containing Parafield had higher digestibility ($p < 0.05$) than those containing Morgan at P80. The digestibility was highest ($p > 0.05$) in crops containing Parafield at H1, and higher ($p > 0.05$) than Morgan at H1 and H3. Crops with the lowest digestibility were those containing Morgan harvested at H2 and H3 and Parafield at H2.

Table 6. The effect of the pea variety and pea sowing rate, and of the pea variety and stage of triticale maturity at harvest on digestibility (DOMD, g kg^{-1}) of triticale–pea forage crops grown at Murrumburrah, NSW.

Pea Variety	Pea Sowing Rate (kg ha^{-1})		Triticale Maturity at Harvest		
	40	80	Boot	Flower	Milk
Morgan	658.2 ^{ab}	649.4 ^{a}	696.3 ^{c}	636.9 ^{a}	628.2 ^{a}
Parafield	663.2 ^{bc}	670.6 ^{c}	712.3 ^{d}	636.8 ^{a}	651.6 ^{b}
p value	0.038			0.038	
l.s.d$_{(p < 0.005)}$	10.95			13.37	

Values within pea variety × pea sowing rate and pea variety × triticale maturity combination with different superscript letters (a, b, c, d) are different ($p < 0.05$).

The crude protein content varied with the main effects of harvest ($p < 0.001$, l.s.d$_{(p < 0.005)}$ = 4.44) and pea variety ($p = 0.007$, l.s.d$_{(p < 0.005)}$ = 3.48), and the interaction between triticale and pea sowing rates ($p = 0.005$) (Table 7). The crude protein content declined ($p < 0.05$) with each successive harvest to be 139.6, 117.4, and 102.0 g kg^{-1} DM at H1, H2, and H3, respectively. Though the difference was small, the CP content of crops containing Morgan (122.1 g kg^{-1} DM) was higher ($p < 0.05$) than those containing Parafield (117.3 g kg^{-1} DM). The crude protein content was higher ($p < 0.05$) for P80 compared to P40 for T15 and T30 crops, while the CP content of P80 crops declined ($p < 0.05$) with the triticale sowing rate, such that T15 > T30 > T45.

Table 7. The effect of triticale and pea sowing rate on the crude protein content (g kg^{-1} DM) of triticale–pea forage crops grown at Murrumburrah, NSW.

Triticale Sowing Rate (kg ha^{-1})	Pea Sowing Rate (kg ha^{-1})	
	40	80
15	115.9 ^{a}	133.8 ^{c}
30	114.4 ^{a}	124.6 ^{b}
45	112.8 ^{a}	116.5 ^{a}
p value	0.005	
l.s.d$_{(p < 0.005)}$	6.02	

Values with different superscript letters (a, b, c) are different ($p < 0.05$).

Differences in the WSC content between treatments was small, but the main effects of the pea sowing rate ($p = 0.014$, l.s.d$_{(p < 0.005)}$ = 6.19), pea variety ($p < 0.001$, l.s.d$_{(p < 0.005)}$ = 6.07), and harvest ($p = 0.009$, l.s.d$_{(p < 0.005)}$ = 8.12) were all significant. The water-soluble carbohydrate content was higher ($p < 0.05$) for P40 than P80 (163.2 vs. 155.9 g kg^{-1} DM); was higher ($p < 0.05$) for Parafield than Morgan crops (166.6 vs. 152.4 g kg^{-1} DM); and declined ($p < 0.05$) with harvest so that H1 (166.4 g kg^{-1} DM) was higher ($p < 0.05$) than H3 (153.6 g kg^{-1} DM), while H2 (158.5 g kg^{-1} DM) was intermediate and not different to either.

Significant differences in the ADF content occurred due to the triticale sowing rate ($p < 0.001$), harvest ($p < 0.001$), and the interaction between the pea sowing rate and pea variety ($p = 0.009$) (Table 8). There were also significant differences in the NDF content due to harvest ($p < 0.001$) and the interaction between the triticale sowing rate and the pea sowing rate ($p = 0.043$) (Table 8). The acid detergent fiber content was lower ($p < 0.05$) for T15 (281.0 g kg^{-1} DM) compared to T30 (288.8 g kg^{-1} DM) and T45 (292.0 g kg^{-1} DM), and varied ($p < 0.05$) such that H3 (264.4 g kg^{-1} DM) < H1 (287.5 g kg^{-1} DM) < H2 (309.7 g kg^{-1} DM). Similarly, NDF also varied ($p < 0.05$), such that H3 (451.4 g kg^{-1} DM) < H1 (480.7 g kg^{-1} DM) < H2 (510.1 g kg^{-1} DM). The ADF content of the P80 Parafield crops was lower ($p < 0.05$) than either the P40 Parafield or both P40 and P80 Morgan crops. The lowest ($p < 0.05$) NDF content occurred when the highest rate of pea was sown with the lowest rate of triticale; in contrast, the highest ($p < 0.05$) NDF occurred when the lowest rate of pea was sown with the highest rate of triticale. Within the pea sowing rate, the NDF content increased ($p < 0.05$) between T15 and T45.

Table 8. The effect of the pea sowing rate and pea variety on the acid detergent fiber (g kg^{-1} DM) content and of pea sowing rate and triticale sowing rate on neutral detergent fiber (g kg^{-1} DM) content of triticale–pea forage crops grown at Murrumburrah, NSW.

Pea Sowing Rate (kg ha^{-1})	Pea Variety		Triticale Sowing Rate (kg ha^{-1})		
	Morgan	**Parafield**	**15**	**30**	**45**
40	291.7 ^{b}	287.4 ^{b}	481.0 ^{b}	487.2 ^{bc}	498.4 ^{c}
80	293.0 ^{b}	276.9 ^{a}	449.3 ^{a}	479.5 ^{b}	489.2 ^{bc}
p value	0.009			0.043	
l.s.d$_{(p < 0.005)}$	6.28			14.91	

Values within the same interaction and with different superscript letters (a, b, c) are different ($p < 0.05$).

4. Discussion

These experiments were conducted to test the hypotheses that (1) a higher pea–triticale content leads to increased forage feed value; (2) forage quality of triticale–pea crops declines with increasing plant maturity; and (3) forage-type peas have higher quality than a semi-leafless variety. We can report that the DOMD and CP content of the crops in these experiments was within the range reported for similar crops in Australia and overseas [10,25,33,34], and could therefore be considered typical. We concluded that our results do not support the first hypothesis, and that a higher pea–triticale content leads to increased forage value. A higher pea content did not increase digestibility, and, though CP content was higher for P80 than P40 crops when sown at T15 and T30, the impact of this additional CP on liveweight gain was predicted to be only minor. For example, the increase in liveweight gain by young growing castrate male lambs fed these crops as the sole diet was estimated to be <2% [35]. Furthermore, the additional gain would be restricted to crops harvested at the boot stage (H1) when DOMD was highest. This observation is consistent with Jacobs et al. who similarly reported that peas did not consistently and significantly improve nutritive value when grown in combination with triticale [25].

Furthermore, our second hypothesis, that forage quality declined with maturity, as determined by digestibility and CP content, was proven true. The average digestibility and CP content declined by 68 and 37 g/kg, respectively, between the boot (H1) and milk stage (H3) harvests. The magnitude of this decline in digestibility and CP content was within the range previously reported for mixed cereal–legume crops grown across a range of environments [10,11,14,25,33,36].

Finally, we found the effect of pea variety on forage quality was equivocal and, therefore, we consider our third hypothesis to be neither proven nor disproven. Despite the average pea content of Parafield crops being lower than Morgan crops (384.8 vs. 486.4 g/kg), the digestibility of Parafield crops was 21.2 g/kg higher than Morgan at the higher pea sowing rate. However, within a pea variety, the pea sowing rate did not affect digestibility. Furthermore, the digestibility of crops containing Parafield pea was 16.0 and 23.4 g/kg higher than those containing Morgan when harvested at the boot (H1) and milk (H3) stages of cereal development, respectively. This is possible due to a higher digestibility of, triticale, or both species compared to Morgan. However, the lack of difference between Parafield and Morgan crops at P40, when triticale represented a greater proportion of the crops, would favor the likelihood of higher Parafield digestibility. It would also require the Parafield digestibility advantage to be sufficiently large in order to counter the effect of reduced pea content of Parafield crops, indicating substantially higher digestibility than Morgan.

Interestingly, the digestibility of Parafield crops increased between H2 and H3. Previous research has indicated that cereal crops, including triticale, continue to decline after the boot stage up to and including the milk stage, equivalent to H1 and H3, respectively [13,36–38].

However, some crops can increase digestibility thereafter due to increasing starch accumulation [39,40]. A possible explanation based on our experiment is the increased pea content at H3 compared to H2; however, the proportion of pea did not differ between harvests and, therefore, we discount that possibility. Alternatively, the digestibility of the pea fraction may have increased during this period; however, this was not measured. An increase in the pea digestibility or the metabolisable energy (ME: MJ kg^{-1} DM) content following an initial decline has been reported in some experiments, but not in others [16,25,41]. It would also indicate a difference in the pattern of digestibility change between the two pea phenotypes. A search in the literature indicated limited data on digestibility changes for a range of pea types and varieties grown under the same conditions. More importantly, we were unable to find any published literature on changes in digestibility that compared a range of different pea types and varieties grown under the same conditions. Based on the apparent differences observed in this experiment, it is therefore recommended that future research should investigate the digestibility of different pea types and varieties at different stages of maturity to identify superior varieties.

The average CP content of crops containing Morgan was higher than those containing Parafield, but the difference was small (4.8 g/kg DM) and unlikely to be of any practical significance. Furthermore, considering that the Morgan pea content was, on average, 26% higher than Parafield, it is highly probable that the CP content of Parafield plants was higher than Morgan plants, but this was not measured. Given the trends in the pea content, DOMD and CP between the two crop types, a relatively higher sowing rate of pea and/or a lower rate of triticale for Parafield crops compared to Morgan crops has merit. However, further experimentation to compare crops with equal proportions of pea and for a range of pea types and varieties is required to confirm the biological and economic merit of this.

The content of water-soluble carbohydrates reflected the content of crop triticale, following treatments that increased the triticale content, i.e., using Parafield and a lower pea sowing rate, which increased WSC, though differences were small and would have no practical or biological significance either for livestock or during conservation. Similarly, a higher triticale content was associated with a higher NDF content, though differences were also small. However, the effect of higher triticale content on ADF content was equivocal, with reduced ADF on P80 compared to P40 crops, but no difference for Morgan. We speculate that the ADF content of Parafield was lower than both Morgan and triticale, which were likely similar, consistent with the fact that Parafield has higher digestibility.

Previous experiments have reported a diverse range in yields for similar forage crops from a range of environments [12,14,36,42–47]. The yield difference between years in these experiments was substantial and reflected differences in the growing season rainfall between years [19]. The yields achieved in 2010 were high but not inconsistent with other reports for forage and grain crops grown under ideal conditions in Australia or overseas [13,44,48]. The yields were generally unaffected by both the triticale or pea sowing rate, which is consistent with a previous study [49]. This indicates that plants are compensated by increased tillering and/or each plant growing when lower sowing rates are used. The exception was in 2010 when growing conditions were very favorable and highest yields were associated with the highest sowing rate of pea or the lowest sowing rate of triticale. We believe that these conditions allowed the pea to capitalize on their more indeterminate growth habit and continue to accumulate biomass for a prolonged period.

Different seasons also had a marked effect on the crop DM content at harvest. In addition to higher yields, higher growing season rainfall was associated with lower DM crops. These crops require more extensive wilting to reduce moisture content, but yield may reduce wilting rate because less forage is exposed to solar radiation. Consequently, with regards to higher yielding, low DM crops will have greater field and respiration losses during wilting, which will be exacerbated when conditions are less favorable, i.e., cool and overcast conditions. Slower drying rates also increase the risk of exposure to rain and greater losses. Conversely, lower growing season rainfall crops beneficially had a higher DM content, but exceeded the recommended level of 350 g/kg for chopped silage when harvested at the milk stage in 2011, making compaction more difficult. We observed that the variability in DM and yield has practical implications, as hay and silage help to manage crop production during wilting. With higher yielding, lower DM crops require more active intervention, including conditioning and tedding, in order to achieve a wilt within a short time period.

The yields exceeded that of a typical self-regenerating annual pasture, which is the most common pasture type in the region [50]. These pastures are normally grazed but can be conserved as hay or silage. More importantly, liveweight gain is estimated to average 1148 kg ha^{-1} (with a range of 443–2790 kg), if fed as the sole diet to 35 kg, six-month-old, crossbred (Border Leicester x Merino or Dorset x Merino) castrated male (wether) lambs [35], assuming 70% utilization of the forage harvest. This favorably compares with lamb production from pasture (914 kg ha^{-1}: range 512–1315 kg ha^{-1}), allowing for higher pasture ME (12 vs. 11.7 MJ kg^{-1} DM with no decline over time) than that observed for the best crops. Interestingly, despite an increase in yield with successive harvests, estimated lamb production per hectare remained essentially unchanged as the yield increase was offset by a reduction in ME after H1. The estimated lamb growth rates at H2 and H3 were 55.7% and 50.1% of H1, respectively [35]. Lower harvesting, storage, and feedout costs, as well as slower lamb growth, indicate that harvesting at H1 is likely to be the optimum harvest time. This is consistent with recommendations for cereal and cereal–vetch crops grown in the same region [14,51].

5. Conclusions

We found that triticale–pea crops have yield and quality attributes which make them a viable forage conservation option, and that optimum harvest stage will be a tradeoff between increasing yield and declining quality as crops mature. That will undoubtedly vary between countries and depend on the relative harvesting and feedout costs, as well as generated income. Thus, farmers are required to have a sound knowledge of both in order to achieve the best financial outcomes. We also found that any effect of the sowing rate of either species or the crop pea content on the yield or quality was inconsistent, minor, and sporadic. Hence, we concluded there is flexibility in selecting sowing rates for each species, at least within the range of rates tested. We recommend that farmers adopt sowing rates based on local recommendations and establishment (seed) costs. We did consider the idea that differences in quality between pea varieties and/or types are likely based on the apparent higher quality of Parafield compared to Morgan. However, further research is still needed to confirm if these findings are true for other cereal species/varieties and pea varieties and growing environments. Most importantly, we concluded that these crops will allow farmers to routinely produce forage reserves to offset feed deficits caused by seasonal and extreme (e.g., drought) weather patterns. We advocate that advisors promote this technology as a risk management strategy so that livestock systems can become more resilient and that livestock production can become more sustainable all year round.

Author Contributions: Conceptualization, J.W.P.; methodology, J.W.P.; formal analysis, J.W.P.; investigation, J.W.P. and C.A.R.; resources, J.W.P.; data curation, J.W.P.; writing—original draft preparation, J.W.P.; writing—review and editing, J.W.P.; supervision, J.W.P. and C.A.R.; project administration, J.W.P.; funding acquisition, J.W.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research received funding from Rural Industries Research and Development Corporation (now AgriFutures Australia) through support provided in project PRJ-003603.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: All relevant data are contained within the paper. Contact the corresponding author if further explanation is required.

Acknowledgments: The authors acknowledge the support provided RIRDC and the NSW Department of Primary Industries.

Conflicts of Interest: The authors declare no conflict of interest.

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