The potential of forage brassicas to produce herbage for mixed farming systems

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Abstract
Forage brassicas are not commonly utilised in Australian mixed farming systems. Integrating forage brassicas into these systems may improve crop rotations and livestock productivity, but their adoption is limited mostly due to a lack of knowledge of the most suitable species and the potential systems benefits from their use. In seven field experiments carried out in 2011-2013 (Phase 1) and 2018 (Phase 2) across a range of environments, including Eastern and Western Darling Downs QLD, North West and Central West NSW, and Avon Wheatbelt WA, the biomass production of a range of forage brassica species were compared with other annual forage benchmark species. In Phase 1, forage rape cultivars were able to produce 80-90% of the biomass of forage cereal controls, but there were some differences between the diverse forage brassica types across growing environments. In Phase 2, Experiments 4, 5 and 7, several of the forage brassicas produced similar ($P > 0.05$) maximum biomass as forage oats. Conversely, in Experiment 6, maximum biomass of forage oats was higher ($P < 0.001$) than all other species. Maximum biomass of raphanobrassica cv. Pallaton and forage rape cv. HT-R24 were similar ($P > 0.05$) to forage oats at three of the four sites, whilst performance of the other forage brassicas was variable between sites.

Key Words
Forage brassicas, biomass, mixed farming

Introduction
In lower rainfall, sub-tropical regions of the mixed farming zone, there have been few winter forage crop options available other than forage cereals (mainly oats). Cereal forage crops increase the risk of weeds, soil borne pests and diseases in the farm rotation. Forage brassicas have several attributes that make them suitable for mixed farming systems. These attributes include low establishment costs, an ability to accumulate high biomass of high nutritive value that can be used strategically to fill feed gaps, natural soil bio-fumigation characteristics for a pest and disease-break between cereal rotations (Kirkegaard and Sawar 1998), rotational herbicide use, and a wide sowing window. In the semi-arid subtropics, canola for oilseed is unprofitable or risky due to dry/hot conditions during grain fill (Robertson and Holland 2004). Forage brassicas could serve a similar role in crop rotations but with reduced risk and the capacity to improve livestock productivity.

Adoption of forage brassicas is currently limited due to a lack of understanding of the species most suited for varying production systems and environments, with potential systems benefits from their use. This paper reports seven separate experiments where the biomass of a number of forage brassica species were compared to other annual forage benchmark species across various locations in the Australian mixed farming zone. Forage nutritive value (e.g., digestibility and crude protein) were also determined in Phase 2 (data not reported). These experiments aimed to determine the benefits forage brassica genotypes for different production environments.

Methods
Site details
In two phases of experiments, the relative biomass production of forage brassicas was compared with annual forage benchmark species. In Phase 1 (2011-2013), three independent field trials examined the relative above ground (leaf/petiole and stem) biomass production of commonly used forage brassicas compared to forage cereals (oats or barley) or forage pea across three locations in Eastern Darling Downs QLD and North West NSW. In Phase 2 (2018), four independent field trials examined a wider range of forage brassica species, including some newly released species and/or cultivars, and compared them with forage oats across environments in the mixed-farming zone (Eastern and Western Darling Downs QLD, Central West NSW, and Avon Wheatbelt WA). The details for each of the experimental sites including location, soil type, sowing date, rainfall and irrigation received over growing season (mm), and N applied (kg/ha) are presented in Table 1.

Table 1. Site location, soil type, sowing date, growing season rainfall, and N applied for the six experimental sites.

Experiment No.	Site location	Soil type	Year	Sowing date	In-crop rainfall + irrigation (mm)	N applied (kg/ha)
1	Pilton, Eastern Darling Downs QLD	Black vertosol	2011	21 May	132	0
2	Formartin, Eastern Darling Downs QLD	Black vertosol	2012	21 June	171	100
3	Tulloona, North West NSW	Black vertosol	2013	5 June	83	0
4	Pampas, Eastern Darling Downs QLD	Black vertosol	2018	20 June	154 + 100	100
5	Condamine, Western Darling Downs QLD	Grey vertosol	2018	11 July	132	100
6	Greenthorpe, Central West NSW	Red Kandosol	2018	21 June	198	40
7	York, Avon Wheatbelt WA	Grey sandy loam	2018	26 June	233	100

Measurements and statistical analyses

In Phase 1, above ground biomass of forage brassicas and the other annual forages was collected from 0.5-1.0 m^2 quadrats in replicated (n = 4) plots. In Phase 2, 10 forage brassica species were compared to forage oats. Maximum edible biomass, including both bulb and leaf/petiole portions in bulb producing species, was collected from 0.5 m^2 quadrats in replicated (n = 4) plots. A linear mixed model using REML was used to analyse the data in ASReml-R version 3.0/64. The level of significance was set at $P < 0.05$.

Results

Phase 1 – Preliminary evaluations of forage brassica cultivars (Experiments 1-3, 2011-2013)

Across all 3 sites in Phase 1, the best of the forage brassicas yielded slightly lower (80-90%) than the forage cereal or legume controls (Table 2). There was some variation amongst the forage brassicas, with leaf turnip cv. Hunter often yielding less than forage rapes, and in some cases there were cultivar difference between forage rape cultivars. At the Pilton site, all of the forage brassica species (kale, forage rapes cv. Winfred and Titan, and leafy turnip cv. Hunter) had similar ($P > 0.05$) biomass production to forage barley cv. Urambie. At the Formartin site, forage rapes cv. Interval and cv. Leafmore produced as much ($P > 0.05$) biomass as forage oats cv. Genie, which was significantly higher ($P < 0.001$) than all other forage brassica species and forage pea cv. Morgan (Table 2). At the Tulloona site, all forage brassica species grew similar biomass to forage pea cv. Morgan ($P > 0.05$).

Table 2 Above ground biomass (leaf/petiole and stem portions), and the days after sowing (DAS) this is reached for various forage brassicas, and annual forages at sites in Eastern Darling Downs QLD (Experiments 1, 2) and North West NSW (Experiment 3).

Species	Cultivar	Pilton, 2011 (Experiment 1) 114 DAS (t DM/ha)	Formartin, 2012 (Experiment 2) 111 DAS (t DM/ha)	Tulloona, 2013 (Experiment 3) 99 and 153 DAS (t DM/ha)
Forage barley	Urambie	9.2^a	-	-
Forage oats	Genie	-	7.4^b	-
Forage pea	Morgan[1]		3.2^a	5.7^a
Kale	Unknown[2]	7.6^a	3.3^a	4.6^a
Forage rape	Winfred[1]	8.0^a	3.5^a	4.4^a
	Titan	7.7^a	-	-
	Interval[2]	-	6.0^b	4.9^a
	Leafmore[2]	-	5.8^b	4.0^a
Leafy turnip	Hunter	5.9^a	3.1^a	-

[1]Maximum edible biomass at 99 DAS; [2]Maximum edible biomass at 153 DAS (Experiment 3)

Phase 2 – Genotype by environment studies (Experiments 4-7, 2018)

At the Pampas site, maximum edible biomass of seven of the forage brassica species was not significantly different ($P > 0.05$) to forage oats cv. Flinders. Maximum edible biomass included bulb portions for bulb turnips cv. Green globe and cv. Rival, leaf turnip cv. Hunter, forage radish cv. Graza, and fodder beet cv. Jamon whilst maximum edible biomass of raphanobrassica cv. Pallaton, and forage rape cv. HT-R24 included leaf/petiole portions only. Of these, maximum edible biomass was achieved at 138 DAS for forage oats and fodder beet, 119 DAS for raphanobrassica, and 111 DAS for the other forage brassica species (Table 3).

Table 3 Maximum edible biomass (bulb and/or leaf portions), rank (% of average maximum edible biomass on a site basis) and the days after sowing (DAS) this is reached for various forage brassicas, and forage oats at four varying sites (Experiments 3, 4, 5 and 6) across the Australian mixed farming zone.

		Eastern Darling Downs QLD (Experiment 4)			Western Darling Downs QLD (Experiment 5)			Central West NSW (Experiment 6)			Avon Wheatbelt WA (Experiment 7)		
Species	Cultivar	Edible biomass (t DM/ha)	Rank (%)	DAS	Edible biomass (t DM/ha)	Rank (%)	DAS	Edible biomass (t DM/ha)	Rank (%)	DAS	Edible biomass (t DM/ha)	Rank (%)	DAS
Forage oats	Flinders	7.47^{d}	147	138	3.45^{d}	159	139	-	-	-	5.09^{f}	157	134
	Eurabbie	-	-	-	-	-	-	3.65^{c}	174	113	-	-	-
Raphanobrassica	Pallaton	6.26^{bcd}	123	119	3.09^{cd}	148	139	1.69^{ab}	81	113	4.54^{ef}	140	134
Forage rape	HT-R24	4.72^{abcd}	93	111	2.00^{abcd}	98	139	2.03^{ab}	97	113	3.83^{def}	118	134
	Goliath	4.29^{abc}	84	119	2.76^{bcd}	129	113	2.21^{b}	105	113	3.37^{cde}	104	134
	Winfred	4.41^{abc}	87	119	2.39^{bcd}	108	113	1.94^{ab}	92	113	2.90^{bcd}	89	134
Bulb turnip	Green globe	5.28^{bcd}	104	111	1.90^{ab}	92	113	1.25^{a}	59	113	3.81^{def}	118	134
	Rival	6.68^{cd}	132	111	2.20^{abcd}	108	113	1.65^{ab}	79	113	3.65^{cde}	113	134
Leaf turnip	Hunter	6.03^{bcd}	119	111	1.65^{abc}	79	113	1.74^{ab}	83	113	3.42^{cde}	106	134
Kale	Regal	3.58^{ab}	71	119	1.30^{ab}	63	113	2.39^{b}	114	179	2.28^{bc}	70	134
Forage radish	Graza	4.77^{abcd}	94	111	2.43^{bcd}	116	113	2.05^{ab}	98	113	-	-	-
Fodder beet	Jamon	5.33^{bcd}	105	138	-	-	-	-	-	-	0.30^{a}	9	134
Swede	Domain	-	-	-	-	-	-	-	-	-	1.67^{ab}	52	134

Differing superscripts within columns indicate significant differences between the forage species ($P \leq 0.05$).

At the Condamine site, the forage rapes, bulb turnip cv. Rival, forage radish cv. Graza, and raphanobrassica cv. Pallaton produced similar ($P > 0.05$) maximum edible biomass to forage oats cv. Flinders. Raphanobrassica had greater ($P < 0.001$) maximum edible biomass than kale cv. Regal and bulb turnip cv. green globe, whilst all other forage brassicas were similar ($P > 0.05$) to one another. Maximum edible biomass of forage oats, raphanobrassica, and forage rape cv. HT-R24 was achieved at 139 DAS, and 113 DAS for all other species (Table 3).

At the Greenthorpe site, maximum edible biomass of the forage oats cv. Eurabbie was higher ($P < 0.001$) than all of the brassica species. Forage rape cv. Goliath and kale cv. Regal produced greater ($P < 0.001$) maximum edible biomass than bulb turnip cv. Green globe. All other species did not vary ($P > 0.05$) from one another. Kale reached maximum biomass at 179 DAS compared to 113 DAS for all other species. Fodder beet did not germinate at the site and thus was not included (Table 3).

At the York site, maximum edible biomass of raphanobrassica, forage rape cv. HT-R24 and bulb turnip cv. Green globe were similar ($P > 0.05$) to forage oats, whilst all other species were lower ($P < 0.001$). Fodder beet produced lower ($P < 0.001$) total edible biomass (despite having bulb) than all other forage brassica species, except for swede cv. Domain of which it was similar to ($P > 0.05$) (Table 3).

Discussion/conclusion

These experiments have shown there is significant potential to use forage brassicas across mixed farming zones as an alternative to forage cereals. In particular, some new genotypes (e.g. raphanobrassica cv. Pallaton and forage rape cv. HT-R24) consistently produced edible biomass comparable to forage cereals across 3 of the 4 sites they were grown in, demonstrating the potential of forage brassicas within the lower and medium rainfall mixed farming zone. We also found leafy turnip cv. Hunter, and some bulb turnips, were less tolerant of dry conditions than other forage brassicas, which may limit their use to higher rainfall zones. Further research is ongoing to better understand adaptations of genotypes across varying climates and to understand how these options may complement other forage sources in a farm feed system. The nutritive value of these forages including digestibility, crude protein, mineral and vitamin, and anti-nutritional compounds will also be further investigated to better quantify their capacity to support high productivity in grazing animals. It is expected that by providing a wide sowing window, the capacity to maintain forage nutritive value and to diversify both crop or forage rotations, forage brassicas could provide diverse roles in mixed crop-livestock farming systems.

References

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