Ley Farming Systems Trial Douglas Daly Research Farm 1994 - 2002

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Acronyms and Abbreviations	Full form
ADMA	Agricultural Development and Marketing Authority
AMG	Annual mission grass
ARAR	Annual Research Achievements Report
BLW	Broadleaf weed
CDU	Charles Darwin University
CRCNA	Cooperative Research Centre for Northern Australia
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DDRF	Douglas Daly Research Farm
DITT	Department of Industry, Tourism and Trade
DLRM	Department of Land Resource Management
DPIR	Department of Primary Industry and Resources
GHG	Greenhouse gas
LFST	Ley Farming Systems Trial
LWT	Liveweight
MLA	Meat and Livestock Australia
MP	Mixed pasture
NT	Northern Territory
NTG	Northern Territory Government
RIRDC	Rural Industries Research and Development Corporation
SR	Stocking rate (L=Low, M=Medium, H=High)
TAR	Technical Annual Report
TNRM	Territory Natural Resource Management

Contents

Summary

The main agricultural land use across the 'Top End' of the Northern Territory (NT) was historically extensive cattle production based on native pastures. The potential of the perceived abundant soil and water resources for cropping and improved pastures, and the increased demand in the live cattle export market, stimulated interest in a sustainable agricultural system. This was based on the integration of grazed legume-based ley pastures in rotation with a cereal grain crop to maximise synergies between the production systems.

A long-term Ley Farming Systems Trial (LFST) was conducted at Douglas Daly Research Farm (DDRF) from 1994 to 2002. This assessed the integration of six key components; Pasture Production, Cattle Production, Grain Crop Production, Soil Health, Weed Management, and Economics.

The demand for resilient farming systems in the 2020s provided the impetus to collate the historical DDRF LFST. Although access to the original data was limited, previous interpretation in historical reports (e.g. Technical Annual Reports) enabled a range of results to be presented here. This allowed for some conclusions and recommendations on findings from the LFST, although complex interactions require further analysis and interpretation.

Pasture Production

Improved pasture species are a key component of increasing cattle productivity in the Top End. The pasture phase in the LFST was either a pure legume (*Centrosema pascuorum* cv. Cavalcade), termed 'Cav-only', or a legume-grass mix (Cavalcade / *Urochloa mosambicensis* cv. Nixon, 'Sabi grass'), termed mixed pasture (MP). The ley pasture treatments were either 1^{st}- year or 2^{nd}- year pastures, divided into either Cav-only or MP. Each pasture treatment was grazed at three stocking rates (SR) over the Dry season. Biomass yield and botanical composition, including non-desirable broadleaf weeds and grasses, were assessed twice yearly in May and November. The main weeds were sicklepod (*Senna obtusifolia*), Hyptis (*Hyptis suaveolens*) and spiny Sida (*Sida acuta*), and grass weeds, predominantly annual mission grass (AMG) (*Cenchrus pedicellatus*). Pasture biomass management in November was critical for mulch management of the 2^{nd}-year pasture prior to sowing sorghum.

The pasture species dynamics were complex, but a number of consistent trends were recorded. Generally, the MP treatment produced greater biomass than the Cav-only treatment prior to introduction of cattle grazing over the Dry season. Mixed pasture May yields for individual paddock records ranged from 7624 to 10639 kg/ha for 1^{st}-year pastures and 7212 to 13527 kg/ha for 2^{nd}-year established paddocks. Comparatively, the Cav-only yields ranged from 4703 to 8840 kg/ha for 1^{st}-year and 5677 to 13218 for 2^{nd}-year pastures. These paddock biomass yields were considered excellent and supported the introduction of subsequent cattle grazing SR treatments.

The proportion of Cavalcade in the MP declined in the 2^{nd}-year pasture following the 1^{st}-year pasture. This was mostly attributed to perennial grass 'coming away' quicker at the start of the Wet season, providing a competitive advantage, compared to the annual Cavalcade establishing from seed. Selective grazing of the legume component within the MP over the Dry season also contributed to the decline in proportion of Cavalcade. Maintaining the legume-grass balance in the MP required strategic management of timing of grazing and weed dynamics.

The Sabi and Cavalcade generally regenerated well following the sorghum crop, which negated the cost of sowing for a 1^{st}-year pasture. Stocking Rate effects on biomass were not generally observed at the May measurements but were evident at the (limited) November data.

Crop Production

A grain crop rotation was a fundamental component of the ley farming system, underpinned by adoption of no-tillage practices. Crop production was assessed as grain yield (kg/ha) of sorghum as well as biomass yield of the stubble. Sorghum (*Sorghum bicolor*) yield (grain and stubble for subsequent dry season grazing) was compared following the two different ley pasture treatments (Cav-only versus MP).

There were problems with sorghum establishment across most years due to planter and insect problems, and bird damage. Poor sorghum population contributed to increased annual mission grass (*Cenchrus pedicellatus*) (AMG) establishment. The sorghum following the Cav-only pasture generally provided better yields compared to the sorghum following the MP. This is probably attributable to a combination of increased nitrogen contribution from the Cavalcade, less AMG due to use of selective herbicides in Cavalcade, and generally better sorghum populations due to easier planting into the Cavalcade mulch. There was variability between years, with the 2001/02 average yields (3567 and 3033 kg/ha following Cav-only and MP respectively) the best achieved across the LFST.

Cattle production

The cattle production component in the LFST was supported by a strong live export market for young high grade Brahman cattle. Increased cattle productivity can be achieved through the use of improved pastures in the higher rainfall areas of the 'Top End', and grazing crop residues. The LFST compared grazing practices aiming to maintain liveweight over the Dry season and arrest the late season liveweight loss to improve breeder and export enterprises efficiencies.

LFST paddocks, either Cav-only or mixed legume-grass (MP), were grazed at three stocking rates categorised as Low, Medium and High. Introduction of cattle onto the treatment paddocks corresponded with the main weaning round - usually around late April/early May to enable assessment of weight gain over the Dry season on saved improved pastures or sorghum stubble. Cattle were weighed every four weeks after introduction onto LFST paddocks, and final cattle weights recorded when the paddocks were destocked. This was generally at the end of the Dry season (@120-140 days grazing period), but timing varied according to season and pasture availability within the treatment paddocks.

Generally, the Low SR consistently resulted in the highest LWT gains (kg/hd) compared to the Medium and High SRs, within the Cav-only and the MP treatments, both 1st year and 2nd year pastures, irrespective of year. This was not unexpected. The effect of ley pasture treatment on cattle weight gain was inconsistent across seasons. Acknowledging variability, the average LWT gain varied from 18.4 kg/hd for the high SR on 2nd-year MP to 44.53 kg/hd for the low SR on the sorghum stubble following Cav-only.

Cattle were also used to crash graze paddocks for mulch management prior to sowing sorghum, and some treatment paddocks were also grazed over the Wet season depending on pasture biomass and composition.

Cattle weight gains between different pasture treatments, and different stocking rates across different seasons is a complex dynamic. More detailed statistical analysis would be beneficial to further explore significant effects.

Weed Management

Weed invasion is a constraint in agricultural production systems. A ley farming system incorporating grazing on either a mixed legume-grass pasture or a legume only pasture phase in rotation with a no-till cereal grain crop provides several advantages for weed control. There was no prescribed method for weed management in the LFST, with weed management decisions based on pasture and weed dynamics each season.

It was difficult to conclusively determine stocking rate and ley pasture treatment effects on the weed populations. Observed trends included broadleaf weeds and AMG (annual mission grass) as considerable components of the Cav-only pastures, the 2nd-year MP appeared to have minimal weed populations, indicative of maintaining a robust and competitive pasture, and AMG was the dominant weed in the sorghum crop, irrespective of the preceding ley pasture treatment.

Weed populations in the Cav-only paddocks were mostly managed through application of imazethapyr (e.g. Spinnaker®) although timeliness of application was an issue some seasons, especially for the self-sown regenerating Cavalcade establishing as a 1st-year pasture post-sorghum. There were limited herbicide options available for mixed pastures, so a herbicide roller and slashing were used as options where feasible, but these were considered to have limited application at a larger industry level.

Soil Health

Incorporation of a legume-based ley pasture in a farming system was considered to underpin improvements in overall soil health, such as increased soil nitrogen and soil organic matter. A reduction in nitrogenous fertiliser to the sorghum grain crop due to the residual nitrogen from the legume-based ley pastures was hypothesised to be a synergistic benefit in the cropping system.

Resource-intensive soil sampling and analysis were conducted. However, it appears that interpretation of soil nitrogen data, and comparison of effect of the two ley pasture treatments to the subsequent sorghum grain crop, and contribution of the legume component to the grass component within the MP in the ley phase, was not quantified. Initial results for the first two years indicated that the legume ley contributed more nitrogen than the MP ley to the cereal crop rotation, and that the legume component contributed to good MP grass biomass production in the absence of nitrogen based synthetic fertilisers.

Bithell *et al.* (2013) conducted a comprehensive analysis of changes in the soil pH and oxidisable carbon, suggesting that a near-complete (although variable) LFST data set was available at that time, but other soil nutrition parameters were not evaluated. They found that Cavalcade had lower pH and lower oxidisable carbon concentrations compared to the MP, and that grazing had no significant effect on either of these parameters. However, differences were often rotation or sample date specific, which prohibited drawing general conclusion about ley pasture treatment effects.

The incorporation of legumes into agricultural systems for improved soil health and productivity is currently seen as a major avenue for increased farming resilience and supporting reduction in carbon emissions.

Economics and Modelling

Production synergies were expected between the different enterprises within the LFST. These included the soil nitrogen contribution from the legume component reducing requirement for synthetic nitrogen fertilisers, and stubble as a by-product of the sorghum grain crop contributing to increased cattle liveweight gains and reduced turn-off times. Gross margin budgets were developed for grain crops and cattle production in the Douglas-Daly in the early 1990s but it does not appear that an economic analysis was conducted based on the LFST to evaluate synergies between the grazing and cropping enterprises.

Agricultural production models informed by factors such as soil characteristics, climatic variables and crop growth physiology enable simulation of different scenarios to assess farming system performance. The LFST intended to collect extensive baseline data to inform a farming system modelling scenario with Cavalcade and cattle grazing practices to help assessment of long-term validity and applicability of a ley farming system in the Douglas-Daly region. It appears that no modelling was done incorporating the LFST trial data, but this could potentially be done with the historical raw data on variables such as cattle weight gains, pasture yields and known soil parameters.

Economic evaluation and model development would be an essential criterion of any future assessment of an agriculture farming system.

Conclusion

The eight-year LFST initiated in 1994 was one of the most ambitious and complex agricultural research projects conducted by the NT Government. It compared cattle production at three stocking rates on two different ley pasture treatments, grown in a two-year rotation with a cereal crop.

The mixed grass-legume pasture generally provided higher pasture biomass and corresponding cattle liveweight gains over the Dry season grazing period, and opportunistic and strategic grazing over the Wet season. However, maintaining the composition and contribution of the legume in a perennial grass – annual legume pasture sward proved difficult. The legume-based pasture (Cavalcade), while providing good cattle liveweight gains in critical periods during the Dry season, 'crashed' earlier with minimal biomass available at the transition from the Dry season to the Wet season, requiring earlier destocking of paddocks.

These characteristics contributed to the evolution of industry preference for legume-only pastures to be primarily grown for high quality hay, and the use of perennial grass-only pastures as the basis for intensive grazing.

The more recent focus on agricultural resilience and reduced carbon emissions has seen renewed interest of incorporation of legumes into improved pasture systems. Improved no-till planting technologies into existing grass pastures may aid in facilitating adoption of mixed pastures.

The best cattle liveweight gains were generally on the sorghum stubble following the Cavalcade ley pasture rotation. However, the cost-effectiveness and gross margins of sorghum grain production as an enterprise appeared to be negligible. Sorghum production had numerous constraints, ranging from poor crop establishment sown no-till, especially into the mixed pasture paddocks, weed competition, mulch management, and significantly, bird damage at both the early seedling emergence stage, and at grain fill and maturation.

The issues documented from the LFST continue to persist, and it is unlikely a cereal or legume grain crop will form a component of an integrated farming system in the Top End of the NT in the near future. Demand remains for a suitable crop for rotation with pastures for intensification of cattle production. Cotton production may fill this niche. Grazing these stubbles will not be as feasible as grazing sorghum stubble, but the by-product cottonseed after ginning would be a high-quality supplement within a cattle production system.

The LFST was a complex dynamic research project over a range of seasons, across a range of treatments. Differences in ley pasture type, stocking rates and rotation phase, with subsequent confounding effects on factors such as weed dynamics, soil health and ground cover, and nutrient cycling complicated the interpretation of data. A more detailed scientific statistical analysis of these components may enhance the understanding of the outcomes of the project. Economic analysis and modelling would further enhance this understanding and validation of the system over variable seasons. This may be possible using the historical data.

The collation of results and discussion in this Technical Report aimed to increase the awareness of some of the lessons learnt and the outcomes from the LFST, and to build on historical knowledge to help inform current and future farming system strategies in the Top End to enhance agricultural practices of stakeholders.

Introduction

The soil and water resources of northern Australia have attracted agricultural production for nearly 100 years. Chapman *et al*. (1996) documented the history of agricultural development and commercial practice in the Australian semi-arid tropics, including the Top End of the Northern Territory (NT). Numerous attempts at dryland cropping, from the Agricultural Development and Marketing Authority (ADMA) Scheme of the 1980s, to the initial genetically modified cotton production in the 1990s, and the promise of grain sorghum trials in the 2000s, have yet to result in a large-scale established commercial dryland cropping industry in the NT. Although, the recent two to three years have seen a resurgence in development of a cotton production industry. This was enabled by enhanced genetically modified varieties adapted to northern Australian climate and pest constraints, which had hampered previous industry attempts, and adoption of farming practices suited to northern soil and climate conditions.

The predominant agricultural land use across the Top End was historically based on low-input extensive cattle grazing on native pastures (Winter *et al*. 1996). The advent of the cattle live export in the 1980s, and the continued pursuit to realise the potential of the soils and water of northern Australia, stimulated interest into a farming strategy in which net benefits were enhanced by synergies gained by integrating beef production and cropping (M^c^Cown *et al*. 1985). Critical components of this farming strategy included legume ley pastures in rotation with a grain crop, and use of no-till practices and associated mulch management.

A trial at Katherine, NT, from 1980-1984, compared the potential of native grass pastures, legume ley pastures and permanent sown grass-legume pastures to increase productivity for the live cattle export trade. It was concluded that the strategic use of ley farming systems could provide more intensive and efficient production of young cattle for live export (Winter *et al.* 1996). Jones *et al*. (1991) stated they were aware of only one study in the Australian semi-arid tropics (M^c^Cown *et al*, 1986) in which an experimental ley pasture system had been grazed and animal production data recorded.

The synergies between beef production and cropping were further assessed by Yeates *et al*. (1996) in their review of the operational aspects of ley farming crop production systems in the semi-arid tropics. This system was developed to overcome many of the climatic constraints previously identified for agriculture development (e.g. Bauer 1985), such as high soil temperatures, high rainfall intensity, and inherently poor soil fertility. They concluded that the variability of rainfall in the transition between the Wet and the Dry season, as reported by Mollah (1986), was one of the key constraints for timing of cropping operations, including sowing window, harvest and mulch management. They also concluded that this transition period was a key limitation for livestock productivity, and that increasing the scale of the livestock enterprise to include a portion of perennial pastures was an option to manage this constraint.

These preceding studies supported the potential of an integrated farming system that included crops, pastures and livestock with adapted technologies such as no-till sowing and associated mulch management. Consequently, the NT Dept of Primary Industries initiated a 'Ley Farming Systems Trial' (LFST) at Douglas Daly Research Farm (DDRF) in 1994. This aimed to evaluate a range of components including pasture, crop, and cattle production, and the combined synergies within a ley farming system for sustainable production in the Top End.

The Farming Systems Research Plan was regarded as an exciting and powerful program when introduced in 1995, and the first of its type to attempt to integrate a multi-disciplinary approach to agriculture in the NT. It attempted to develop a strategy to overcome climatic and soil constraints which had thwarted previous attempts at crop intensification. It was acknowledged that developing successful legume-based farming systems in the semi-arid tropics was challenging due to a number of constraints. These include eventual grass dominance of a mixed grass-legume pasture, very rapid legume residue decomposition and loss of mineral nitrogen limiting the benefits of legumes to the system, and a lack of sufficient crop and/or pasture residues in extreme seasons to assist with no-till sowing methods (Jones et al. 1991; McCown 1996).

The major components were categorised into six sub-programs, with designated teams, and clearly defined objectives and strategies. Details of the six sub-programs; Pasture Production, Cattle Production, Grain Crop Production, Soil Health, Weed Management, and Economics, are discussed further below.

The LFST concluded in 2002, but results were not published and remained largely unavailable through traditional academic literature search engines. Several key personnel resigned/retired over the initial phases of the LFST, including Colin McCool (Project Leader), Kandiah Thiagalingam (Soil Scientist) and David Zuill (Cattle Production Scientist). Other personnel, including Rowena Eastick (Weed Scientist), Barry Lemcke (Livestock Production Scientist), and technical staff Nick Hartley and Peter Shotton, had multiple project commitments. This required agility in project management and data collection and collation, and in some part, contributed to the lack of a final report.

The demand for effective farming systems adapted for northern Australia did not necessarily diminish after the LFST concluded in 2002, but industry priorities aligned elsewhere. Local farmers continued to explore options which did not entail the tribulations of grain cropping. Cavalcade (*Centrosema pascuorum* cv. Cavalcade) production evolved from a grazed pasture species to niche production for high quality hay as a significant enterprise to complement cubing and pelleting feed requirements, especially for the live export cattle trade.

However, the resurgence in the early 2020s of a developing cotton industry and the requirement for a sustainable crop rotation, has put the spotlight back onto farming systems. The increasing demand for intensification and diversification of cattle production aligned with a potential decreased future reliance on a live export market, the increasing accountability for carbon emissions, and the need for enhanced resilience of agriculture in the face of climate variability, has supported this renewed interest on sustainable integrated farming systems.

This Technical Report presents the rationale, the method, and results from the DDRF LFST conducted from 1994 to 2002. There were difficulties in accessing the original data, so much of the information presented is from previous interpretation in historical reports (e.g. Technical Annual Reports, TAR). Little statistical analyses were conducted to present in this report; it is possible that a peer-reviewed journal paper could be collated in the future, but this was not the current intent.

This Report discusses some conclusions and recommendations regarding each component, and their interactions, with relevance for present day farming systems in the 'Top End' of the NT. This aims to increase the awareness of the lessons learnt and the findings from the LFST and to recognise knowledge gaps which persist in northern farming systems. This will help inform current farming system strategies and potential research and future development priorities to enhance agricultural practices of stakeholders in the Top End.

Ley Farming Systems Trial

Site description

The LFST was established in what had been Paddocks 56 and 57 at DDRF (Figure 1), consisting of open woodland with native grass understorey and some aerially sown Stylo (*Stylosanthes* spp) pasture. The woodland was progressively cleared, prepared, subsequently divided and fenced into 19 discrete paddocks to allow for the rotation phases and sown to each phase as described below.

Field 56 (28Ha) and 14Ha of field 57 were chained in 1993 as part of the land-clearing process to prepare the area for Phase I (LFST paddocks 1-6) and Phase II (LFST paddocks 7-12). The area was stick-raked, pin-wheeled and the windrows burnt between mid-1994 and October 1994, followed by cultivation using off-set discs and a chisel plough and pin-wheeled three times.

For the Phase I paddocks, the area was harrowed in early December 1994 prior to planting with bull-rush millet. In January 1995, a knockdown herbicide was applied, and the first ley pasture phase was sown from mid-January to early February 1995. For the Phase II paddocks, the area was fertilised with 200 kg/ha of 0-10-20-5, and then offset ploughed again to incorporate the fertiliser. Grain sorghum was planted in the area on 18/12/1995.

The remaining 15 hectares of field 57 was cleared in 1994, then stick-raked, pin-wheeled and windrows burnt in early 1995 to prepare the area for Phase III (LFST paddocks 13-19). The area was then sown with a grain sorghum variety trial on 30/12/1995 for the first grain crop treatment as part of the LFST.

The soil was generally described as ‘Blain’, selected as it is one of the most common soil types used for agriculture in the region. It is described initially by Aldrick & Robinson (1972) and categorised within Deep Red Magnesic Kandosols Under Australian Soil Classification systems (Isbell 2021).

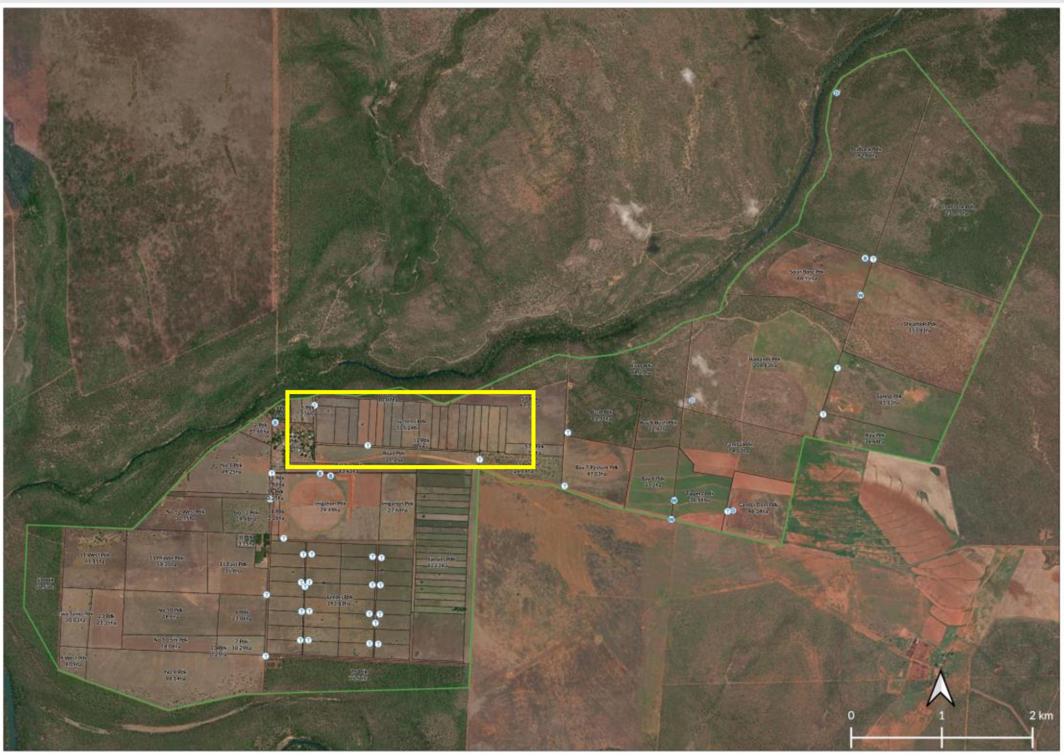


***Figure 1**. Location of LFST (yellow box) within DDRF (green polygon). Paddock 1 at the west to paddock 19 at the east.*

Trial Layout

Establishment of the LFST consisted of plantings in three 'phases' of over the initial three years, each comprised of six paddocks. Subsequently, in any one season, there was a treatment of 1st year pastures (sown or self-sown that year), a treatment of 2nd year established pastures (sown the previous year), and a sorghum crop (planted after two years of pasture). These 'phases' formed the basis for the trial design of three unreplicated ley pasture rotation treatments.

The ley pasture species was divided into two main plot treatments. These were either a pure legume (*Centrosema pascuorum* cv. Cavalcade), termed 'Cav-only', or a legume-grass mix (Cavalcade / *Urochloa mosambicensis* cv. Nixon, 'Sabi grass'), termed mixed pasture (MP). Each main plot pasture treatment was 14 hectares, comprised of three paddocks: a 6-hectare and two 4-hectare paddocks. Each main plot had three split-plot Dry season stocking rate treatments (low, medium or high), which were allocated into the three paddocks (Table 1). These treatments and an additional reference continuous cropping treatment (paddock No.19 of 4 Ha) are described in more detail in the sections below.

The ley pasture treatment was applied over the Wet season, so grazing treatment was the following Dry season.

***Table 1**. The ley farming Pasture type treatment (Mixed Pasture, MP or Cavalcade, Cav-only) or Grain crop in each LFST paddock (Paddock No. 1-19) across years and corresponding Stocking rate (Low, Medium, High).*

YEAR	PADDOCK NO. and STOCKING RATE						
	1 2 3	4 5 6	7 8 9	10 11 12	13 14 15	16 17 18	19
	M L H	L H M	M L H	L H M	L M H	M H L	L
1994/95 Phase I established	MP 1st yr	Cav-only 1st yr	Sorghum	Sorghum	Cleared	Cleared	Cleared
1995/96 Phase II established	MP 2nd yr	Cav-only 2nd yr	MP 1st yr	Cav-only 1st yr	Sorghum	Sorghum	Sorghum
1996/97 Phase III established	Sorghum	Sorghum	MP 2nd yr	Cav-only 2nd yr	Cav-only 1st yr	MP 1st yr	Sorghum
1997/98	MP 1st yr	Cav-only 1styr	Sorghum	Sorghum	Cav-only 2nd yr	MP 2nd yr	Sorghum
1998/99	MP 2nd yr	Cav-only 2nd yr	MP 1styr	Cav-only 1styr	Sorghum	Sorghum	Sorghum
1999/2000	Sorghum	Sorghum	MP 2nd yr	Cav-only 2nd yr	MP 1styr	Cav-only 1styr	Sorghum
2000/01	MP 1st yr sown	Cav-only 1styr	Sorghum	Sorghum	MP 2nd yr	Cav-only 2nd yr	Sorghum
2001/02	MP 2nd yr	Cav-only 2nd yr	MP 1styr	Cav-only 1styr	Sorghum	Sorghum	Sorghum

Pasture Production

Introduction

The 1980s were an auspicious period for introduction of improved pasture species in the NT. Significant investment and resources evaluated a total of 465 new species and cultivars from 1981-1984 across a range of habitats, from the red soils of the Douglas-Daly to the yellow earth podzolic of the Katherine region (Cameron 1989). The aim was to increase the overall productivity of the northern cattle herd, through the provision of higher quality forage compared to native pasture species in the Top End. The identification and availability of improved pasture species formed the basis for inclusion of a pasture production component in the LFST.

The pasture phase in the LFST was either a pure legume termed 'Cav-only', or a legume-grass mix termed mixed pasture (MP). The role of the pasture phase was to:

- Contribute to improved cattle liveweight gains.
- Provide soil health benefits and mulch cover for crop rotation.
- Contribute to soil nutrition, specifically nitrogen (N), for the following crop phase.
- Provide a break in the pest cycle (pathogens, weeds).

This is a dynamic ecological system where legume, grass and weed interact and influence each other and the soil nutrition dynamics. The addition of livestock at three different stocking rates (SR) further complicates this plant-soil interaction due to the effects of variable grazing intensity, selective grazing, trampling and nutrient cycling.

Fertility change, particularly due to nitrogen input from the legume component also aids in species composition shift - usually leading to grass dominance and/or broadleaf weed invasion and depletion of the legume component (Martin 1996). A management strategy to deplete this N "sink" is to sow a cereal crop in rotation.

The LFST was a complex interaction of factors.

In the current agricultural climate with focus on reducing greenhouse gas emissions, the use of higher quality pastures can assist in improving cattle productivity with a subsequent reduction in methane emissions from cattle enteric formation (O'Gara & Eastick 2024). This would be an additional benefit in quantifying the increased productivity of a ley farming system, which was not considered in the initial rationale of the LFST.

Method

The ley pasture treatments were categorised as either 1st- year or 2nd- year pastures, divided into either Cav-only or MP. The 1st-year pastures were sown mechanically in the initial phases, and then reliant on self-sown seed to establish following the sorghum crop. The 2nd-year pastures carried over as established pasture from the 1st year.

Each paddock (paddock numbers 1-19, corresponding to a different pasture/grazing/crop treatment) was assessed for biomass yield and botanical composition, using the BOTANAL procedure (Tothill *et al.* 1992). Sampling was done twice yearly. This was at the end of the Wet season/beginning of the Dry season (May), and at the end of the Dry season/beginning of the Wet season (November).

The May measurements show pasture quality and yield available at the commencement of the Dry season grazing period. The November measurements at the end of the Dry season grazing period indicate the impact of the three different grazing SR treatments on residual biomass, which has implications for mulch management in the 2nd year pasture phase prior to sowing sorghum.

Measurement of pasture species composition during the sorghum phase allowed assessment of the regenerating intercrop as a weed, through either interspecies competition, or providing difficulties during harvest. Regeneration of the desirable pasture species (Cavalcade and Sabi) after the sorghum phase was also evaluated. This was an integral component of the sustainability of the crop-pasture rotation through establishment of a self-sown pasture phase.

Two transects were walked at a slight diagonal down and back up the paddock, with recordings entered onto a palm-top computer in the field approximately every 35 steps, resulting in approximately 40 quadrats assessed per paddock. Plant species were identified and their percentage of total biomass in that quadrat was estimated. Yield was estimated on a scale of 1-10.

Six quadrats (0.5m x 1m) were hand-harvested, separated into their species components in the laboratory (e.g. Sabi grass, Cavalcade, broadleaf weeds, annual mission grass), and dry weights recorded. A regression of these actual weights against estimated yields was conducted and used in the Botanal® analysis for species composition and yields. It appears the species composition was not assessed after 1999, with only total weights recorded. This may have been due to the very labour-intensive nature of separating quadrat biomass into the species components (untwining Cavalcade from Sabi in the MP quadrats in the laboratory was very time consuming).

Quadrats 1 and 6, 2 and 5, and 3 and 4, corresponding to the top, middle and bottom respectively of the paddock, were bulked and ground for submission for nutrient analysis.

Mulch Management

The botanical species assessment conducted at the end of the Dry season/beginning of the Wet season for the 2nd-year pasture informed the mulch management for the subsequent no-till sorghum crop. The two options for managing mulch levels for effective sowing were manipulating grazing pressure and/or use of knockdown herbicide.

Weed Management

The assessment of pasture species composition included recording non-desirable species such as broadleaf weeds sicklepod (*Senna obtusifolia*), Hyptis (*Hyptis suaveolens*) and spiny Sida (*Sida acuta*), and grass weeds, predominantly annual mission grass (AMG) (*Cenchrus pedicellatus*). This was to determine effect of grazing pressure, pasture species, crop rotation and the interaction of these multiple variables, on weed species dynamics.

The May assessment prior to introduction of the cattle indicated weed species which had established over the Wet Season, and indicated the success, or otherwise, of any weed management practices, including herbicide treatments which had been applied. The November assessment indicated dominant weed species which remained after the Dry Season grazing, indicative of selective grazing of the desirable pasture species. Herbicide application and grazing management were the main options used to manipulate weed dynamics. This varied according to species composition and time of season.

Weed management is discussed in a later section as a component of the entire farming system, incorporating the pasture, grain crop, and cattle production phases.

Results and Discussion

Pasture species composition and biomass yields for the May and November measurements (where available) are presented below for each year of the LFST. The sorghum stubble yields, including sorghum stalk and regenerating pasture species, are also provided. Note there was also a substantial portion of sorghum grain (relative to harvested grain yield) on the ground, which was observed to be actively sought by cattle when introduced into the paddocks.

1994/95

The initial Phase I ley pastures (nominated paddocks 1-6) of 14 hectares of Cavalcade (Cav-only) and 14 hectares of Mixed Pasture (MP) were sown on 15 and 16 January 1995. These 1st-year ley treatments established and performed well by the May pasture assessment. The Cav-only and MP pastures produced an average dry matter yield and protein content of 7.0 t/ha and 11.82 % and 7 .58 t/ha and 8.19 % respectively. The Cavalcade to Sabi ratio in the MP ley was 37:63%.

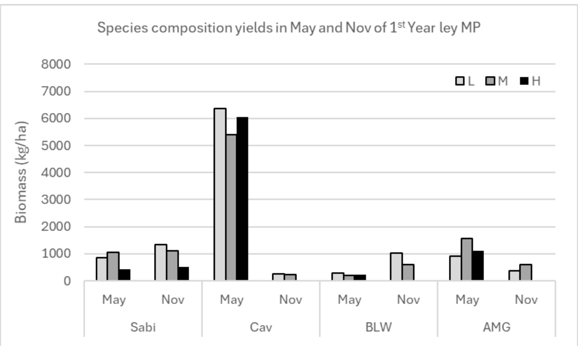
1995/96

The Phase II 1st-year ley pastures were sown in December 1995 (into nominated paddocks 7-12), producing good yields prior to cattle introduction over the 1996 Dry season.

There was the expected decline in total pasture biomass over the Dry season grazing period in the MP and Cav-only treatments in both the 1st-year (Fig. 2.a, b) and 2nd-year pastures (Fig. 3.a, b). There was a less dramatic decline in biomass for the Sabi compared to the Cavalcade component within the MP (1st- and 2nd- year), consistent with the persistence of a perennial grass compared to an annual legume. Broadleaf weeds persisted in the Cav-only pasture treatment (Fig. 3.b).

The average contribution of Sabi and Cavalcade to the total pasture biomass for the May measurements is provided in Table 2. The 1st -year MP had a low proportion of Sabi (10%) due to poor germination, with Cavalcade contributing 72% of the biomass. The 2nd-year MP had a Cavalcade to Sabi ratio of 19:76%, suggesting a shift towards grass dominance compared to the previous season (37:63%). This was attributed to a relative decrease in the proportion of the Cavalcade from selective grazing, a break in dormancy of sown Sabi seed, and competitiveness and seed production from perennial Sabi plants.

The major weeds in the sown areas were AMG, *Hyptis*, *Sida acuta*, and *Crotalaria* species.

a)


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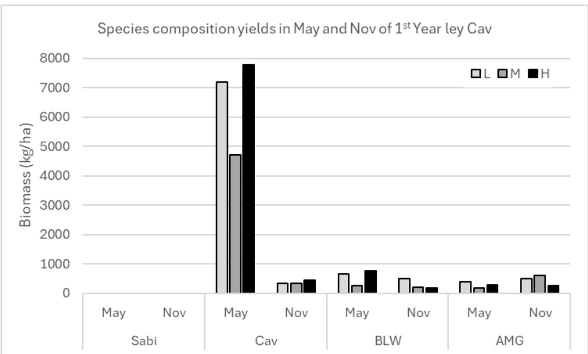


***Figure 2.a,b**. Difference in species composition yield (Sabi, Cavalcade, Broadleaf weeds (BLW), and Annual Mission Grass (AMG)) between May and November (1996) for 1st year ley pasture treatment (MP and Cav-only), across Stocking Rates (Low, Medium, High).*

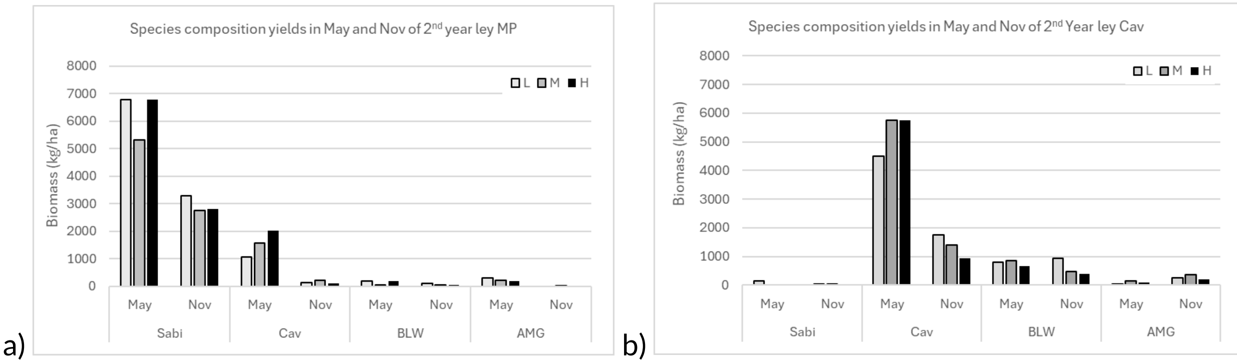


***Figure 3.a,b**. Difference in species yield composition (Sabi, Cavalcade, Broadleaf weeds (BLW), and Annual Mission Grass (AMG)) between May and November (1996) for 2nd year ley pasture treatment (MP and Cav-only), across Stocking Rates (Low, Medium, High).*

***Table 2**. Biomass yields and % of Sabi grass and Cavalcade in different ley pasture treatments (MP and Cav-only) as 1st-year sown, and 2nd-year established pastures, May 1996. Values are averaged across the 3 stocking rates. Total biomass includes all species recorded, including broadleaf weeds (BLW) and AMG (% not specified).*

Ley pasture treatment		Sabi grass component		Cavalcade component		Total biomass (kg/ha)
		Yield (kg/ha)	% of Total biomass	Yield (kg/ha)	% of Total biomass	
1st yr sown	MP	784	10	5933	72	8235
	Cav-only	0	0	6556	84	7772
2nd yr established	MP	6293	76	1550	19	8250
	Cav-only	47	1	5335	83	6437

1996/97

The 1996/97 season was the completion of the first full 3-year rotation, with the Phase I paddocks (1-6) initially sown to either MP or Cav-only over the 1994/95 season now sown to sorghum after two years of ley pasture. Sorghum establishment was generally poor. This is discussed further in the Grain Crop Production section. Species composition data for May 1997 was unable to be located for this report.

November data indicates the Sabi and Cavalcade re-established well in both the MP and the Cav-only pasture treatments following the sorghum crop and grazing of stubble over the 1997 Dry season (Fig. 4). The relatively high Cavalcade component is consistent with abundant germination from the seedbank, in combination with minimal competition from any perennial Sabi grass. Broadleaf weeds were a significant proportion of biomass in the sorghum stubble following the Cav-only pasture, and AMG was the dominant weed in the continuous sorghum treatment.

Phase III paddocks (numbers 13-19) which had been sown to sorghum in 1995/96 after initial land-clearing were now sown to the 1st -year ley pasture treatments. Paddocks were slashed, then subsequently ploughed, due to high levels of vegetative matter (no species data) before sowing of the pasture treatments could occur. All paddocks were fertilised with @200 kg/ha of 0-11-20-6.

The mixed pastures were sown with the trash-culti drill (10 kg/ha Cavalcade and 4.2 kg/ha Sabi). Basagran® (2 L/ha) was applied post-emergence. The Cav-only paddocks were sown with the Mason 8-row planter (7.8 kg/ha). Spinnaker® (400 ml/ha) was applied pre-emergence and Sertin® (1L/ha) applied post-emergence. Some hand-rogueing of the paddocks was conducted due to introduction of sicklepod, sesbania and phasey bean seed with the purchased Cavalcade seed.

There were no May metrics available, but biomass yields for November following the Dry season grazing period for the 1st-year pastures are provided in Figure 5.a. Sabi grass comprised the dominant portion of the MP, consistent with selective grazing of any Cavalcade over the Dry season (and assuming some Cavalcade established prior to the commencement of grazing). There appeared to be an inconsistent SR effect. The Cav-only paddocks had less than 0.5 kg/ha across SRs of biomass remaining, suggesting heavy grazing impact, and consistent with the degradation of vegetative material at the transition period early in the Wet season.

The Phase II (paddocks 7-12) ley pasture treatments sown in 1995/96 remained as a 2nd -year pasture, and fertiliser (0-11-20-6) applied at 200kg/ha. Dense infestations of broadleaf weeds, particularly Hyptis, were present across all paddocks (data not presented), and management actions were required. To reduce weed numbers, the MP paddocks were sprayed with 2,4-D amicide, which resulted in collateral damage to the Cavalcade. This was supported by the near absence of legume biomass by the November measurement (Fig. 5b), although this would have been confounded by selective grazing pressure over the Dry season.

The Cav-only paddocks were slashed, the regrowth sprayed with glyphosate and resown no-till (Cavalcade at 7.8 kg/ha) to reduce soil disturbance and stimulation of broadleaf weed seed germination. Spinnaker® was then applied post-planting pre-emergence (400 ml/ha). Chlorpyrifos (1L/ha) was also applied due to high grasshopper numbers. Sertin® and Basagran® were subsequently applied post-emergence, to manage newly germinating grass weeds and broadleaf weeds respectively. This effectively resulted in the intended 2nd -year Cav-only becoming a 1st -year pasture. Yields were lower than the comparable 1st year sown treatment (Fig.5 a,b).

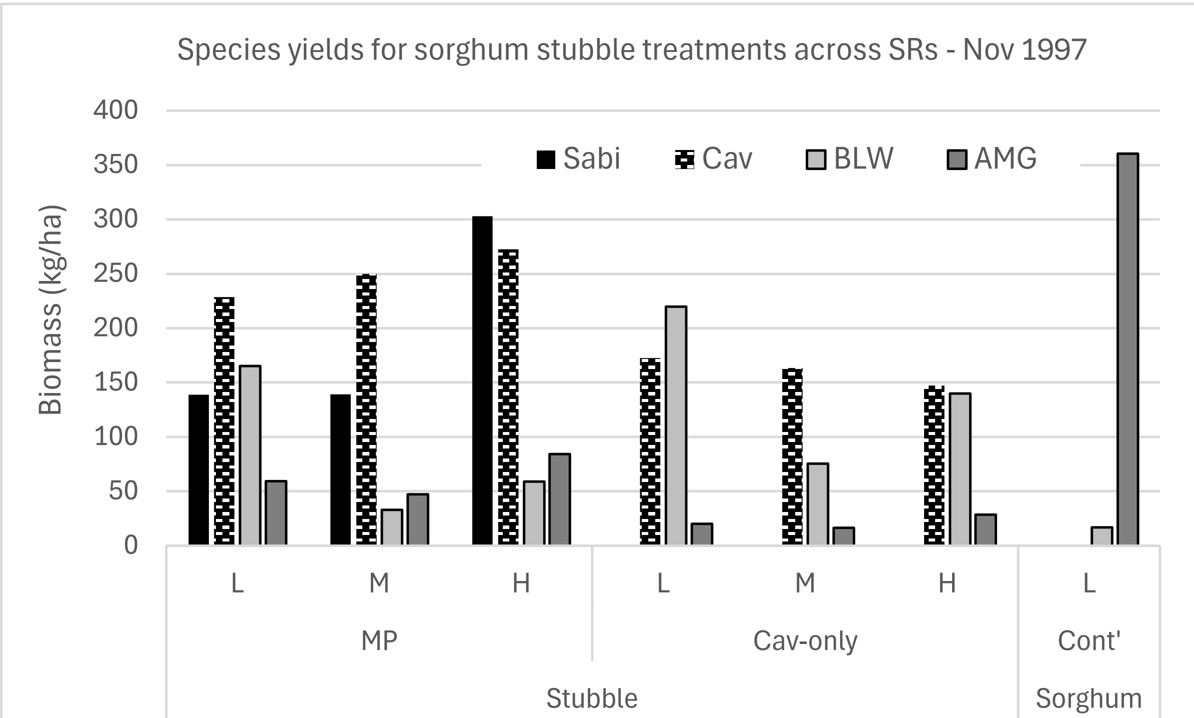
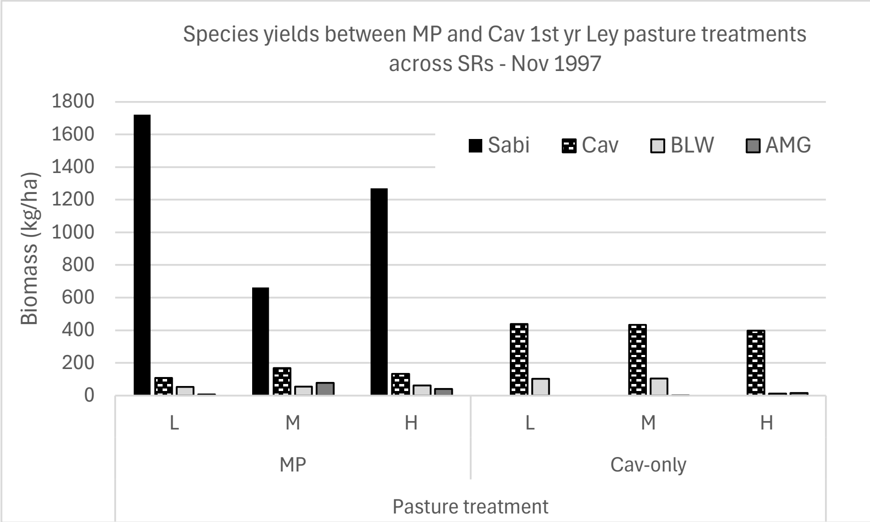


***Figure 4**. Species biomass in November 1997 (Sabi, Cavalcade, Broadleaf weed, Annual Mission Grass) across stocking rates (SRs) indicating regeneration of ley pasture species following the sorghum crop in rotation with the ley pasture treatments (MP and Cav-only).*



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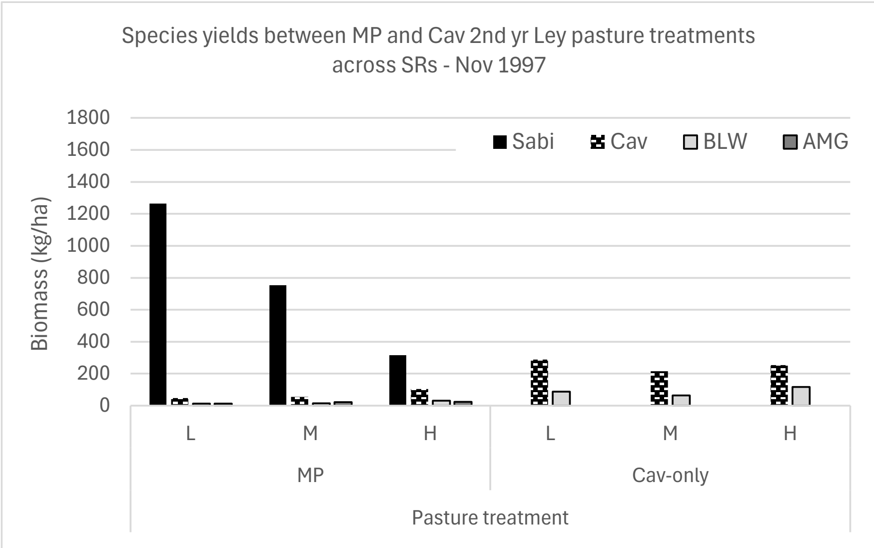


b)

Figure 5.a,b. *Species biomass at November 1997 (Sabi, Cavalcade, Broadleaf weed, Annual Mission Grass) across Stocking rates for 1st year and 2nd year ley pasture treatments (MP and Cav-only).*

1997/98

All paddocks had relatively high pasture biomass at the start of the 1998 Dry season grazing period after good growing conditions over the 1997/98 Wet season. The 1st -year pastures (Fig. 6.a) had average yields (excluding weed species) across SR treatments of 7073 and 5109 kg/ha for the MP and Cav-only treatments respectively. The MP had a good balance of both Sabi and Cavalcade.

The 2nd -year pastures (Fig. 6.b) had average yields across SR treatments of 11054 and 11978 kg/ha for the MP and Cav-only treatments respectively. This excluded weed biomass, although there was a trend for increased broadleaf weeds with increased SR.

The self-sown Sabi and Cavalcade regenerated well after the sorghum crop, with average yields across SR treatments of 4077 and 1937 kg/ha for the MP and Cav-only treatments respectively. This excluded the substantial weed biomass, most of which was AMG. The exception was the MP High SR treatment (Figure 7). This was due to nearly all this paddock being submerged for extended periods with the January floods. The good establishment of the self-sown Sabi and Cavalcade carried over into the 1998/99 Wet season, negating the requirement for sowing the next 1st-year pasture phase.

The high biomass across pasture treatments was attributed to some extent to better weed control (timely herbicide application) and more strategic grazing management (e.g. heavy grazing which reduced AMG density) at the end of the previous wet season.

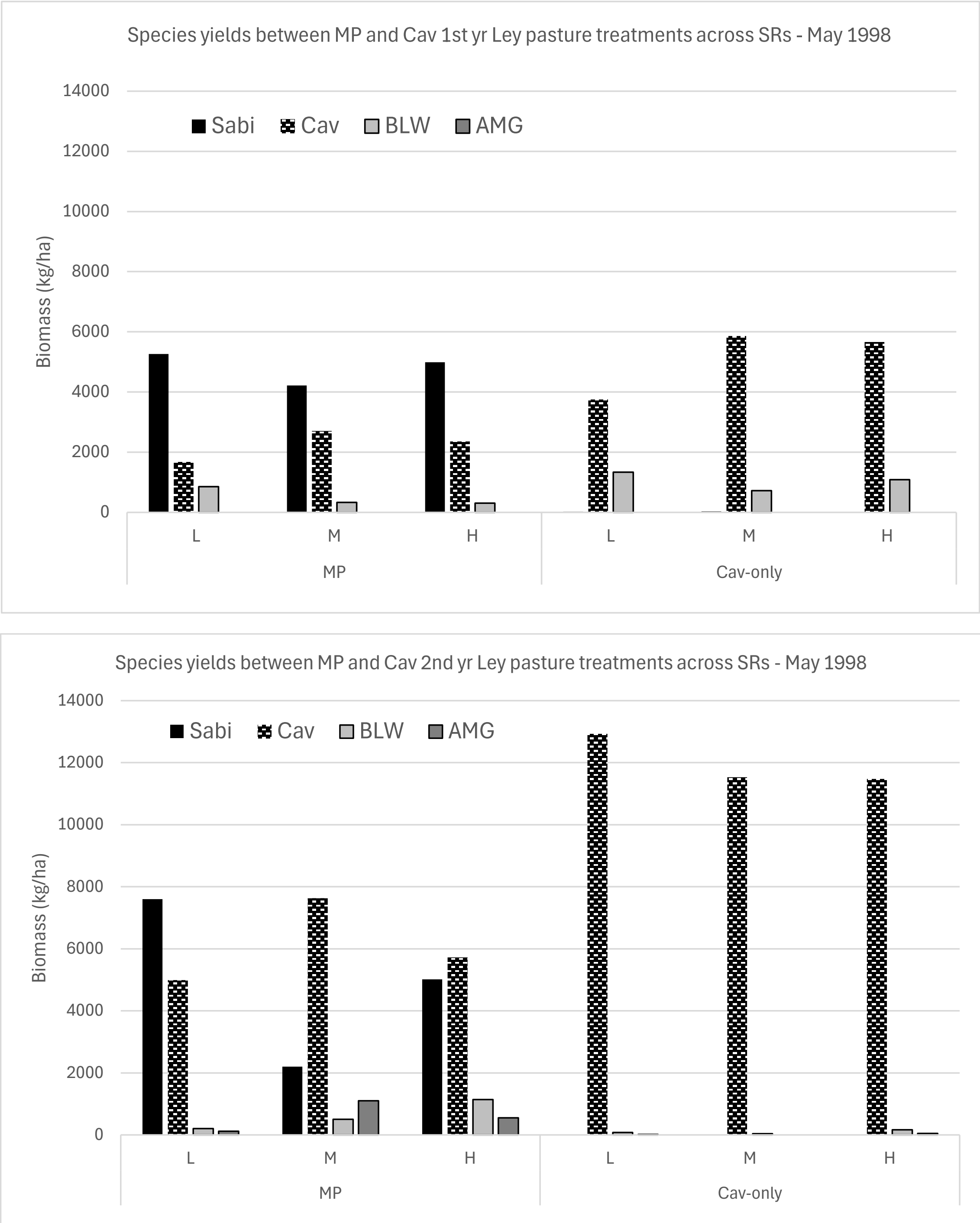
The 1997/98 Wet season was also a record rainfall year with extensive flooding in January (Photo 1). Photo 2 below illustrates the line of inundation; the lower end of the paddocks (foreground in photo) was underwater for an extended period in January. The flood severely damaged the sorghum crop in some paddocks, although areas not inundated did mature to produce grain (Photo 3.a).

There was also a flood effect on the AMG (which was a major weed in the sorghum), effectively drowning any early Wet season seedlings, and seed in the seedbank. The inundation appeared to stimulate the subsequent Sabi and Cavalcade germination and growth, hypothesised due to effect on breaking seed dormancy and hard seededness respectively. The higher end of the paddocks was not inundated, resulting in a dense AMG infestation.

The substantial proportion of broadleaf weed regenerating after the sorghum crop in the Cav-only paddocks in November 1997 (refer Fig. 4 above) required application of a knockdown herbicide, and re-sowing the Cavalcade with a post-plant pre-emergent herbicide (Spinnaker®). This did result in better Cavalcade establishment (e.g. Photo 3.b) and reduced broadleaf weed burden by the time of cattle introduction in June 1998 (Figure 6.a).

Photo 1*. Inundation in January 1998 at the lower end (north) of the paddocks sown to sorghum in December (paddock No's 7-9).*

Photo 2*. The flooding effect evident in May 1998 in mixed pasture regenerating after sorghum stubble (paddock No's 7 & 8). Inundation in the lower end of the paddocks (foreground) reduced the AMG population and appeared to stimulate Sabi and Cavalcade growth (in foreground). Note the fluffy AMG at the top of the photo above the flood water line.*



a)

b)

Figure 6. a,b. *Species biomass at May 1998 (Sabi, Cavalcade, Broadleaf weed, Annual Mission Grass) across Stocking rates for 1st year and 2nd year ley pasture treatments (MP, and Cav-only) prior to introduction of grazing.*

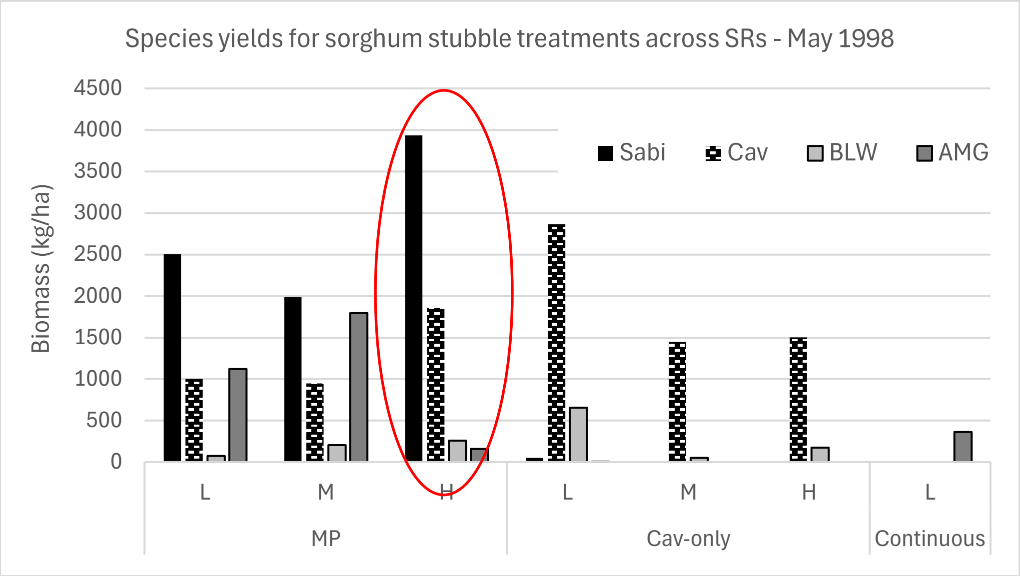


Figure 7. *Species biomass at May 1998 (Sabi, Cavalcade, Broadleaf weed, Annual Mission Grass) across Stocking rates for sorghum stubble following ley pasture treatments (MP and Cav-only). The majority of the H SR paddock (paddock no.9), circled in red, was inundated in January.*

a)

b)

Photo 3. *20th May 1998. Vegetation monitoring prior to introduction of cattle grazing treatments.*
a) Sorghum grain crop following two years of cavalcade ley pasture - note no AMG, and the good regeneration of cavalcade as the understorey.
b) Biomass harvesting a Cav-only pasture for assessment of biomass yield and nutrient analysis.

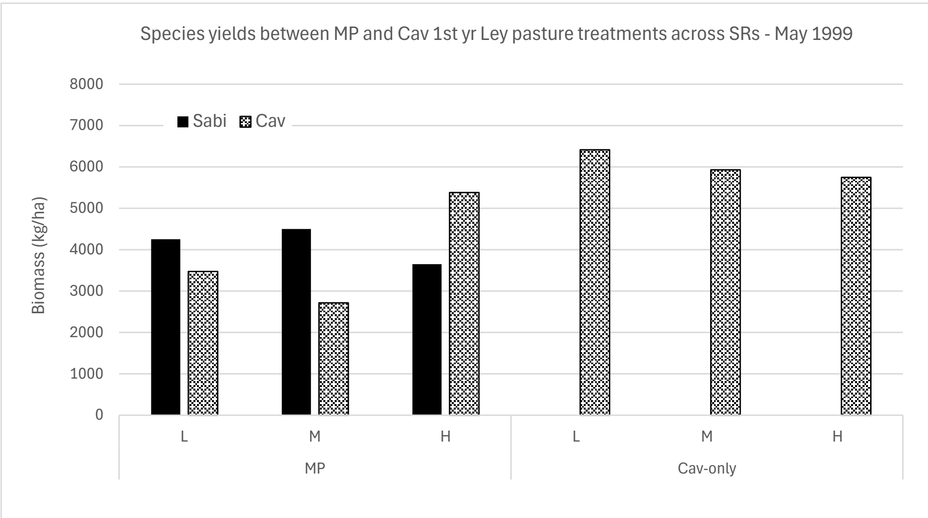
1998/99 Wet season

The top two species only were quantified for species composition. The proportion of Sabi and Cavalcade if they were the top two species is presented in the figures below (Fig. 8, 9) to enable some comparison with previous seasons. No value does not necessarily indicate zero biomass for these species, but no additional data was available.

As discussed for the previous season above, Sabi and Cavalcade regenerated well from the seed bank after the sorghum stubble phase, which negated the requirement for resowing the 1st-year pasture phase over this 1998/99 Wet season. Average yields across SRs were 7993 and 6031 kg/ha for the MP and Cav-only respectively by the May measurement (Fig. 8.a).

It was unclear from historical data what pasture and weed management was conducted for the 2nd -year pastures, but their biomass for the May measurement is presented below (Fig. 8.b). The lack of Cavalcade in the MP suggests that broadleaf weeds may have been a problem, and the paddocks sprayed with a broadleaf herbicide (e.g. 2,4-D Amicide), which would have resulted in collateral mortality of the Cavalcade.

The absence of Sabi in the sorghum stubble paddocks (Fig. 9) suggests weed management which targeted grass weeds in sorghum (e.g. atrazine to control AMG), may have resulted in collateral damage of Sabi grass. Sorghum stalk biomass averaged across SRs was 5712 and 6707 kg/ha for the stubble following MP and Cav-only respectively (data not presented below).



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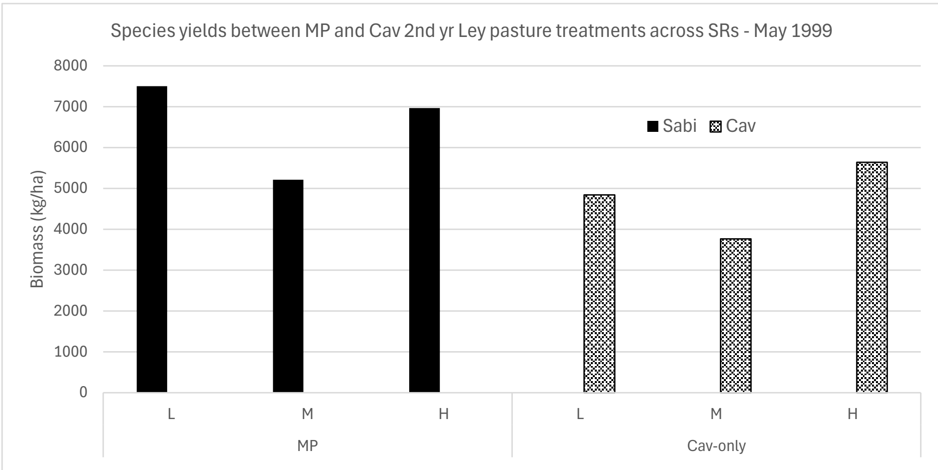


b)

***Figure 8.a,b**. Species biomass at May 1999 (Sabi, Cavalcade) across Stocking rates for 1st year and 2nd year ley pasture treatments (Mixed Pasture and Cav-only).*

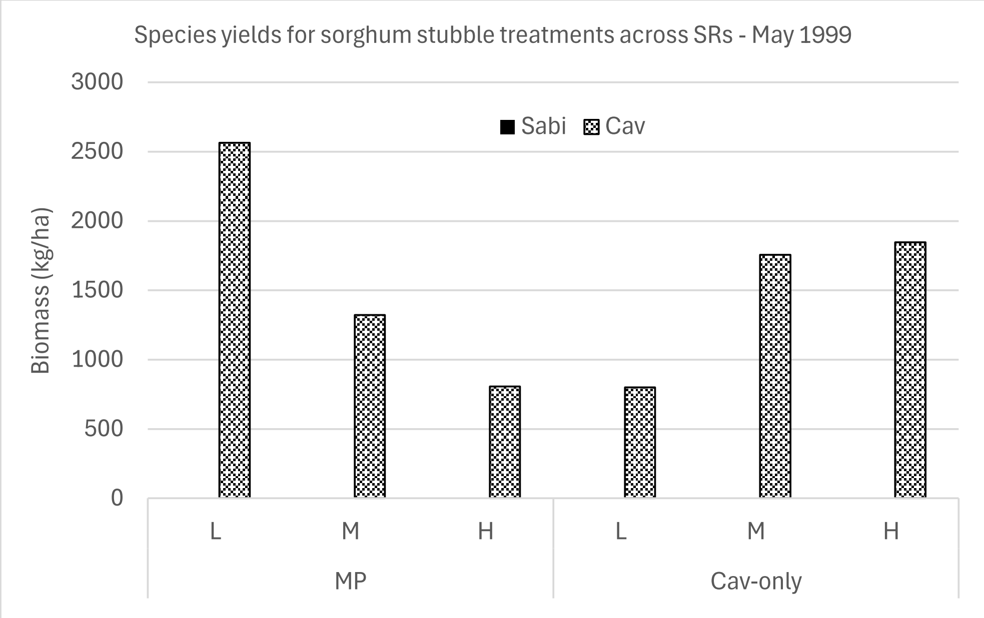


Figure 9. *Species biomass at May 1999 (Sabi, Cavalcade) across Stocking rates for sorghum stubble following the two different ley pasture treatments (MP and Cav-only).*

The May 1999 measurements appeared to be the final season where species composition was collected. Data for November measurements also could not be located post-May 1999. This may have been attributed to the labour-intensive nature of separating quadrats into component species and competing staff resources at the peak Wet season preparation time for crop and pasture sowing in November.

The following seasons, 1999/2000 and 2000/2001 discussed in the sections below present only total biomass data in May. Comparable data is provided for previous years for comparison (Fig. 10). The sorghum stubble data was not separated into species components (Cavalcade and Sabi), so the biomass includes sorghum stalk, contributing to the relatively high total yields (Fig. 10.c).

1999/2000

Sabi and Cavalcade again regenerated well from the seed bank after the sorghum phase over the 1999/2000 wet season; however, additional costs were incurred in the 1st -year Cav-only paddocks because of a weed problem.

The spraying of annual grasses in the Cav-only paddocks at the optimum time - at the break of the season - was complicated by dry weather and stressed plants, and poor feasibility of a Spinnaker® application. (It is unclear from collation of historical data why a grass-specific herbicide such as Verdict® was not applied if annual grass weeds were dominant?). This required a knockdown application of glyphosate to eliminate the high weed burden. It is unclear from historical data whether the establishment of Cavalcade subsequently relied on a second flush of germination, which is generally less robust and dense compared to the first germination flush, or whether replanting occurred.

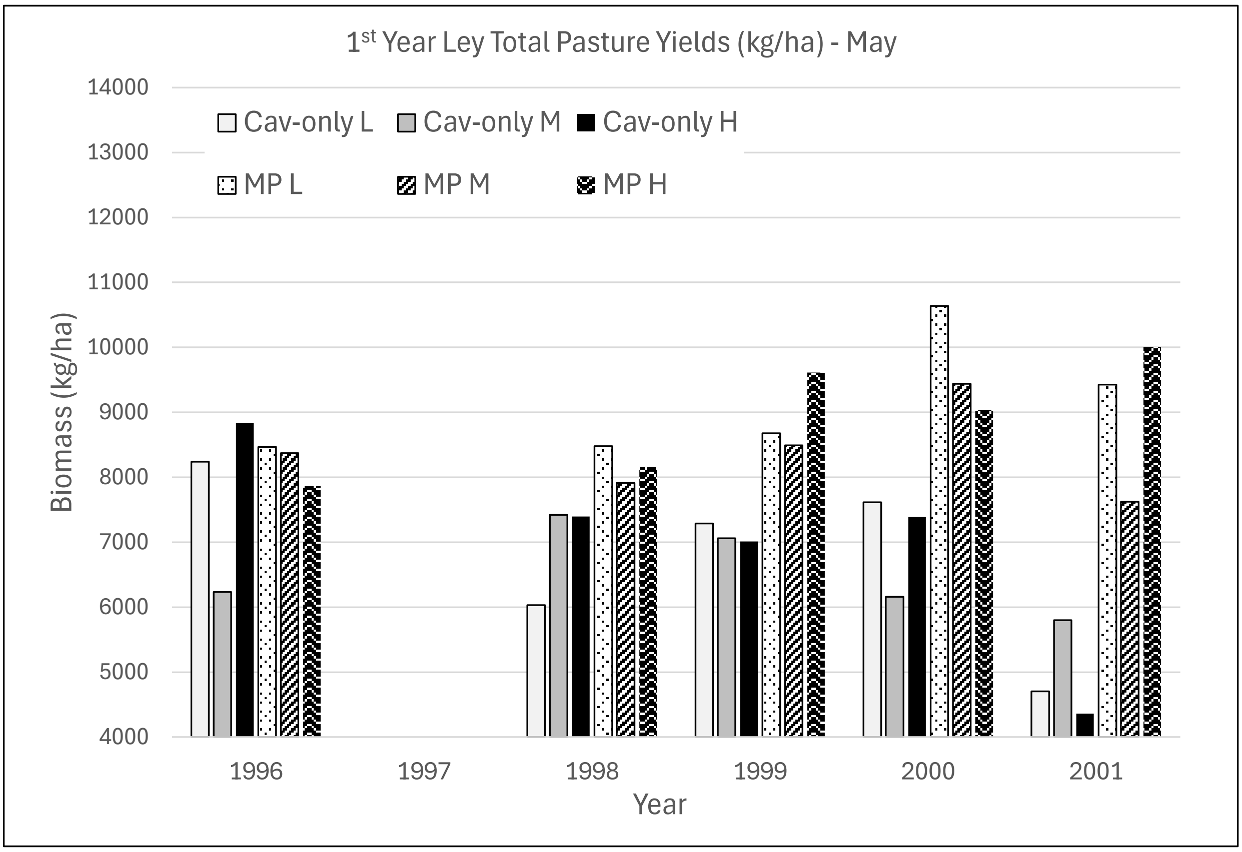
Average biomass for the 1st year pasture treatments across SRs was 7055 and 9705 kg/ha for the Cav-only and the MP respectively (Figure 10a). Average biomass for the 2nd year pasture treatments across SRs was 6719 and 9105 kg/ha for the Cav-only and the MP respectively (Fig. 10.b). Note that this is total biomass, and proportion of weeds is not quantified, but was considered minor relative to the total biomass, but this did differ between treatments.

2000/01 Wet season

Sabi and Cavalcade again regenerated well from the seed bank after the sorghum crop. There was a high proportion of broadleaf and grass weeds (data not provided) in the Cav-only paddocks, so they were sprayed with a knockdown herbicide (glyphosate). Ideally, these paddocks should have been sprayed early with imazethapyr (e.g. Spinnaker®) prior to germinating rains. Consequently, a second flush of Cavalcade seed germination was necessary for pasture establishment, which was relatively poor prior to the 2002 Dry season grazing period due to a lower-than-average Wet season.

Average biomass for the 1st year pasture treatments across SRs was 4955 and 9018 kg/ha for the Cav-only and the MP respectively (Fig. 10.a). Average biomass for the 2nd year pasture treatments across SRs was 6130 and 8606 kg/ha for the Cav-only and the MP respectively (Fig. 10.b). Note that this is total biomass, and proportion of weeds is not quantified, but was considered minor relative to the total biomass, but this did differ between treatments.

The sorghum stubble biomass was relatively consistent across pasture treatments and years (Fig. 10.c), with the exception of 1998, which was attributed to the January 1998 flood. There was a trend for the High SR to have decreased biomass compared to the Low and Medium SRs on the Cav-only pasture compared to the MP treatment.



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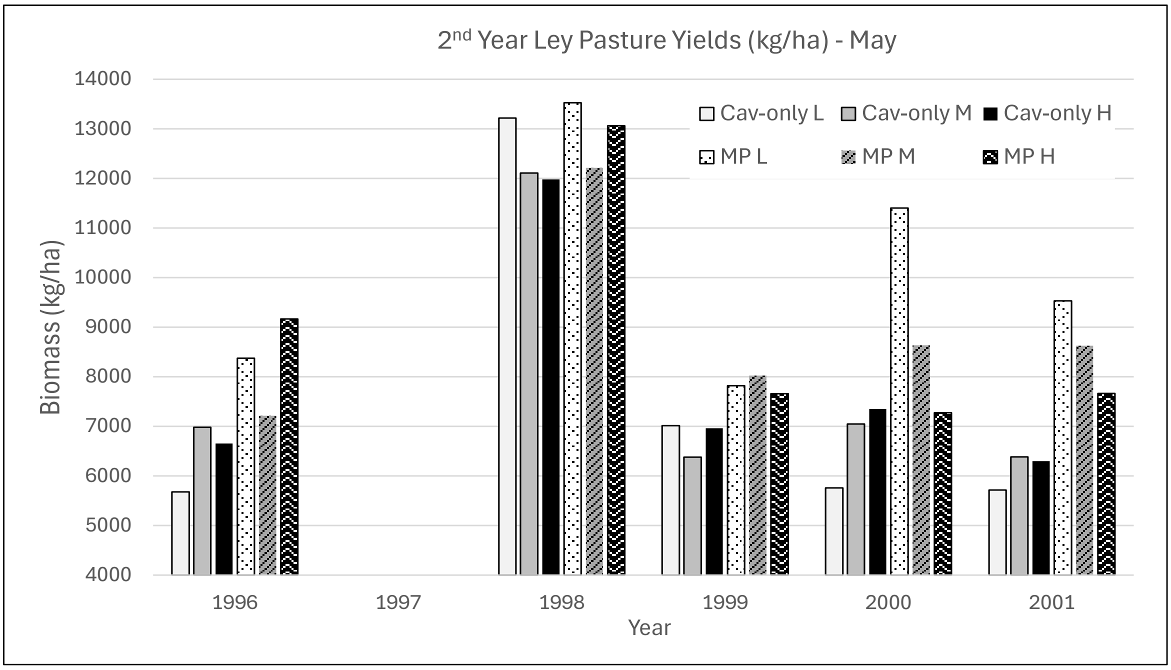

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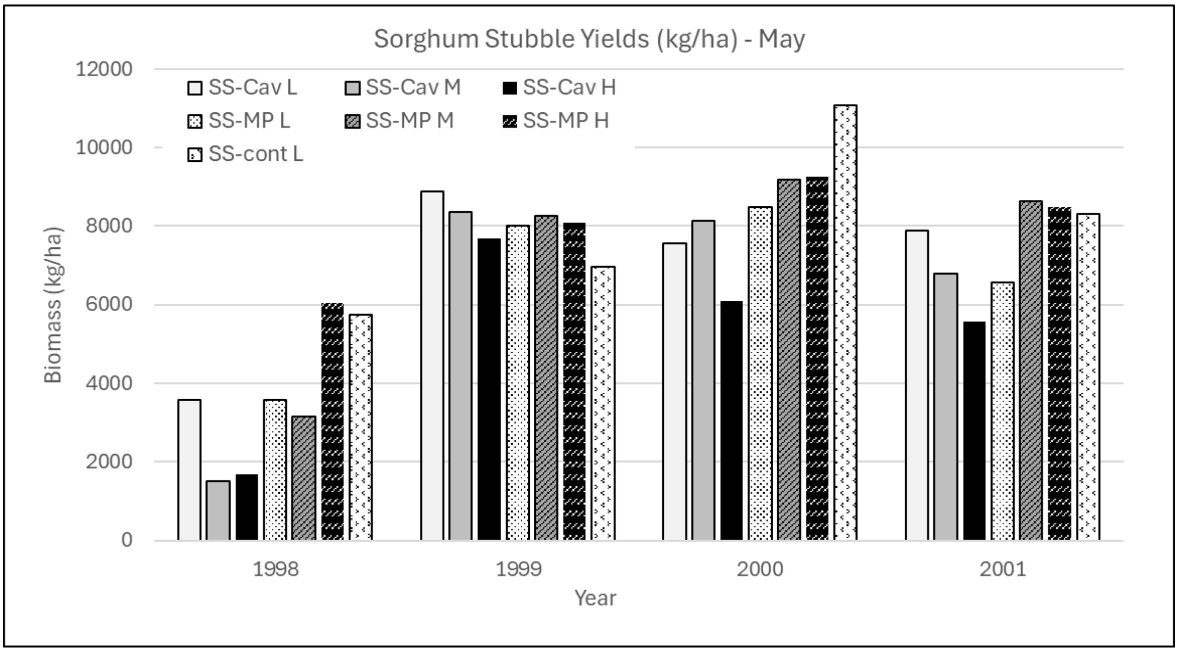


c)

***Figure 10. a,b,c**. 1st year and 2nd year Pasture (Cav-only and MP) yields, and Sorghum stubble yields at each SR treatment (Low, Medium, High) at May measurement (end of Wet season) across years.*

Sequence over seasons

Photos 4. a-f and 5. a-e illustrate an example of the visual changes in species composition and yield over time in the ley pasture treatments. The first sequence (Photos 4. a-f) shows the changes in the Cav-only pasture / sorghum rotation. The second sequence (Photos 5. a-e) shows the changes in the MP / sorghum rotation. These visual observations were consistent with results from vegetation monitoring data and Botanal® analysis, as presented in the relevant year results above.

***Photo 4.a**. 17th October 1996. The 2nd year grazed Cav-only pasture. The foreground is the high SR (paddock No.5), and the background is the low SR (paddock No.4).*

***Photo 4.b**. 14th November 1996. The 2nd year grazed Cav-only pasture. The foreground is the high SR (paddock No.5), and the background is the low SR (paddock No.4). Regenerating Cavalcade from the seedbank was just starting to emerge stimulated by initial Wet season rains. Note in the far background (paddock with tree), cattle were used to crash-graze the mixed pasture paddocks to reduce mulch levels prior to sowing sorghum in December.*

***Photo 4.c**. 29th August 1997. Cattle were introduced on the 5th June 1997 at the high SR into this paddock (No.5) of sorghum stubble following the Cav-only ley pasture.*

Photo 4.d*. 5th November 1997. Sorghum stubble was re-shooting (ratooning) with the Cavalcade understorey just starting to re-establish from self-sown seed (paddock No.4). Cattle had been removed from these Cav-only paddocks earlier than the MP paddocks due to low feed levels.*

Photo 4.e*. 16th December 1997. Cavalcade establishing well from the seedbank (paddock No. 4). Paddock was not grazed over the wet season to enable Cavalcade to bulk up prior to the Dry season grazing period. This also allowed the Cavalcade to flower and set seed to replenish the soil seedbank.*

Photo 4.f*. 25th March 1998. Weeds, predominantly Hyptis, had begun to dominate the pasture (paddock No.4). Paddock had been sprayed with Spinnaker® earlier in the season, but weeds were too well advanced. For 'remedial' weed control, half of each 1st year Cav-only paddock for each grazing treatment (L, M, H) was slashed (RHS of photo), and the other half rolled with the herbicide roller (LHS of photo). Flowering was late, and seed set was lower than expected, probably due to the Jan 1998 flooding.*

***Photo 5.a**. 13th October 1996. The 2nd year grazed MP (paddock No.2) – Sabi grass was beginning to become dominant at the expense of the Cavalcade component. These paddocks were crash-grazed after the Dry season grazing treatments concluded (mid-November), to reduce biomass levels prior to sowing sorghum in December.*

***Photo 5.b**. 29th August 1997. Dry Season grazing at the low SR (paddock No.2) of the sorghum stubble which had followed two years of MP. The stalky clumps are AMG, little sorghum stalk remained. Also note the lick block in the centre foreground - weaners had access to Weanermaster® blocks when they were introduced into the treatment paddocks, then Uramol® blocks through-out the rest of the Dry Season.*

***Photo 5.c**. 8th April 1998. Sabi and Cavalcade both regenerated well from dormant and hard seed over the 1997/98 Wet season- resowing of either species was not necessary after the sorghum phase. Some broadleaf weeds, particularly Hyptis, also emerged after the sorghum phase, demonstrating the difficulty in controlling weeds in the mixed pasture paddocks.*

Conclusion

The pasture species dynamics were complex, confounded not only by imposed treatment differences such as stocking rate, but consequent differences in management options. E.g. Weed management could not be the same between the MP and the Cav-only treatments, which had implications for subsequent biomass production and comparison between the two ley pastures. Conclusions for pasture species production and dynamics was also confounded by the inconsistency in data available. However, a number of consistent trends were recorded.

Winter *et al*. (1996) examined legume ley pastures, including a Cavalcade parent line, reporting yields ranging from 3.6 to 5.6 t/ha, comprised in most cases of more than 70% legume. Mixed pastures were not imposed as one of their ley pasture treatments. The DDRF LFST addressed this gap, by the inclusion and comparison of a legume only (Cav-only) and a mixed grass-legume (MP) treatment. Generally, the MP treatment produced greater biomass than the Cav-only treatment prior to introduction of cattle grazing over the Dry season. This was not unexpected, due to the benefits of synergies in growth habits and physiology between a grass-legume pasture mix.

Mixed pasture May yields for individual paddock records ranged from 7624 to 10639 kg/ha for 1st-year pastures and 7212 to 13527 kg/ha for 2nd-year established paddocks. Comparatively, the Cav-only yields ranged from 4703 to 8840 kg/ha for 1st-year and 5677 to 13218 kg/ha for 2nd-year pastures. These paddock biomass yields were considered excellent and supported the introduction of subsequent cattle grazing SR treatments.

Fluctuations in percentage of Sabi to Cavalcade in the MP were influenced by a range of factors, some of which varied between years, resulting in inconsistencies in the data. Factors included poor initial germination of Sabi (is known to possess seed dormancy, so de-hulled germination-tested seed is essential), flooding, broadleaf weed dominance requiring herbicide application which caused Cavalcade mortality, and dense AMG in sorghum phase requiring herbicide application which subsequently affected Sabi establishment and growth.

General observations once the variable non-controlled factors were considered was that the proportion of Cavalcade in the MP declined in the 2nd-year pasture following the 1st-year pasture. This was mostly attributed to established perennial grass 'coming away' quicker at the start of the Wet season, providing a competitive advantage, compared to the annual Cavalcade establishing from seed. Selective grazing of the legume component within the MP over the Dry season also contributed to the decline in proportion of Cavalcade. The increase in grass proportion is consistent with findings from Winter *et al*. (1996) who found a dramatic increase in grass (not defined) from first to second year in a legume-based ley pasture system.

The Sabi and Cavalcade generally regenerated well following the sorghum crop, which negated the cost of sowing for a 1st-year pasture. Cavalcade was noted to provide intercrop competition as it emerged within the sorghum crop and caused difficulties with grain harvest due to its twining growth habit, but this was not quantified.

Stocking Rate effects on biomass were not generally observed at the May measurements but were evident at the (limited) November data. This was not surprising as the SR treatment was not imposed over the Wet season, although crash-grazing for mulch management occurred in paddocks intended for sowing sorghum. This is discussed further in the Cattle Production section.

Grain Crop Production

The main dryland grain crops historically grown in the Douglas-Daly region have been maize, sorghum, soybean and mungbean (Thiagalingam, *et al*. 1996). Sorghum was seen as the most suitable crop to be grown in rotation with either a legume-only or a grass-legume ley pasture. This was to allow a rotation between a cereal phase, and a phase containing legumes, for numerous benefits including addition of nitrogen to the system, and pest, disease and weed management. Sorghum was sown no-till, consistent with recommendations for reduced risk with seasonal variability and soil and climatic constraints (Abrecht & Bristow, 1996). One paddock (paddock No.19) was sown under continuous sorghum divided into no-till and conventional till, for comparison with the ley rotation treatments.

Introduction

Crop production is a fundamental component of the ley farming system. Extensive dryland cereal crops were attempted in the 1980s, with significant investment in sorghum variety trails, maize crop rotations, peanuts, mungbean and sesame. However, these monocultures were largely unsuccessful. The LFST acknowledged that sorghum was the best cereal crop option and incorporated this as the crop phase to:

- Provide a high protein grain for stock feed.
- Utilise the nitrogen fixed by the legume (Cavalcade) in the preceding pasture phase.
- Provide good quality stubble for grazing.
- Allow selective weed control in different phases of the rotation, with less chemical.
- Enable a break in any disease or pathogen cycle.
- Prevent or reduce the rate of soil acidification.
- Allow flexibility with grain cropping and relative market for cattle.

An integral component of the crop production phase is the incorporation of no-tillage practices. No-till has a number of advantages, as advocated by prior authors (e.g. Abrecht & Bristow, 1996). However, mulch management is critical for success of establishment of no-till crops. Two major agents to manipulate mulch levels are grazing management, and use of knock-down herbicides. The LFST evaluated these management practices in the pasture / crop / grazing phases.

Method

Crop production was assessed as grain yield (t/ha) of sorghum (*Sorghum bicolor*), as well as biomass yield of the stubble for subsequent dry season grazing. Sorghum yield (grain and stubble) was compared following the two different ley pasture treatments (Cav-only versus MP). Direct drilling methods were used for all crops. The exception was one area of Paddock 19 from May 1999 onwards which was placed under conventional cultivation and sowing to allow a comparison (non-replicated) with results from the no-tillage treatments.

Following the initial three-year rotation, the ley pastures successfully re-established after the sorghum crop and did not require sowing. Herbicide inputs on the trial area were often substantial due to problems with both grass and broadleaf weeds.

The crop was subject to nitrogen strips (0 to 240 kg/ha urea) for the Dec-1996 sowing. This was to quantify the differences in the nitrogen contribution from the previous pasture phase between legume only and the legume-grass pasture treatment to the sorghum crop.

A sorghum variety trial was conducted in the LFST paddocks (No's 13 to 17) over the 2000/2001 season as part of the sorghum rotation phase.

Results and Discussion

1994/95

Sorghum was sown into newly cleared paddocks (No's 7-12). (No yield data was available for this report.) This was in preparation for sowing for 1st year pastures the following season (over the 1995/96 Wet season).

1995/96

Sorghum was sown into newly cleared paddocks (No's 13-19). (No yield data was available for this report.) This was in preparation for sowing for 1st year pastures and the 'continuous sorghum' treatment (paddock 19) the following season (over the 1996/97 Wet season).

1996/97

The Phase I (paddocks 16) ley pastures (Cav-only versus MP) were sown no-till to sorghum after two years of pasture, completing the first full 3-year rotation. The paddocks were fertilised with @230 kg/ha of 0-11-20-6. Glyphosate was applied as a knockdown herbicide and sorghum (Feed 'N' Grain® at 7.3 kg/ha) was sown no-till with the Buffalo planter. Dual® and atrazine were applied post-planting pre-emergence. Nitrogen treatments (0, 30, 60 and 120 units of N) were randomly applied within each paddock.

There were problems with sorghum establishment due to planter and insect problems. There was also considerable bird damage. Annual mission grass (*Cenchrus pedicellatus*) was the major weed in these paddocks, particularly where the sorghum population was low. The dense population of AMG in the MP treatment inhibited harvesting (Photo 6), so mechanical grain yields were not obtained. The level of AMG in the Cav-only paddocks was lower (Photo 7), so grain yields were possible (@30 tonnes total for paddocks 4, 5, and 6, average @2100 kg/ha). Less grass weed may be attributable to the use of selective grass herbicides in the previous season.

Sorghum leaves (second youngest true leaf) were sampled for nitrogen and phosphorus analysis. Sorghum was both mechanically harvested and hand-harvested for determination of grain yield under different pasture, and nitrogen, treatments. (Data was not available for this Report). Soil samples were taken in May at 3 depths (0-5 cm, 5-15 cm, and 15-30 cm) for soil nutrient analysis. Sampling for estimation of biomass and Botanal® was conducted in November and May.

Paddock 19 was again sown to sorghum as the continuous crop treatment, divided into conventional till and no-till sowing.

The sorghum paddocks were harvested in mid-late April. Regeneration of pasture species as the understory in these stubble paddocks was good for the Cavalcade but poor for the Sabi. This may have been an interaction with the competition from the AMG in the mixed pastures.

The sorghum following the Cav-only pasture provided the better yields so far compared to the sorghum following the MP. This is probably attributable to a combination of increased nitrogen contribution from the Cavalcade, less AMG due to use of selective herbicides in Cavalcade, and generally better sorghum populations due to easier planting into the Cavalcade mulch.

Photo 6. *Heavy infestation of AMG on the 19th March 1997 in the sorghum following the ley MP treatment (Medium SR, paddock No.1). Mechanical harvesting was not feasible.*

Photo 7. *Sorghum being harvested on the 24th April 1997, following the Cav-only pasture. Note very little AMG.*

1997/98

The Phase II (paddocks 7-12) ley pastures (Cav-only versus MP) were sown no-till to sorghum (Dec 1997) after two years of pasture. These paddocks had been crash grazed by cattle to reduce mulch levels prior to sowing (Photo 8).

The major January 1998 floods contributed to significant sorghum crop loss (e.g. Photo 1), so grain harvest was not conducted. The remaining plants contributed to the grazing component over the 1998 Dry season.

***Photo 8**. 19th November 1997. Cattle crash grazing 2nd-year MP (paddock No.9) to reduce biomass levels to desirable levels (@2.5t/ha) prior to sowing sorghum in December. Variable sorghum establishment was subsequently observed sowing no-till into MP compared to Cav-only, due to nature of Sabi tussocks and root mass.*

1998/99

The Phase III (paddocks 13-18) ley pastures (Cav-only versus MP) were sown no-till to sorghum (Dec 1998) after two years of pasture. Urea fertiliser was applied at 90 kg/ha top dressed, plus starter nitrogen at 38 kg/ha. The initial planting, sown with the buffalo planter, established poorly and was resown, using the Mason drill. A better result was obtained but plant populations were still low. Establishment was a consistent problem with these pastures particularly where Sabi grass was dominant (e.g. paddock No.18, MP Low SR).

Yields would be improved if there were good plant populations at establishment. The crop was harvested in May. The average yield across the SRs (L, M, H) was 1954 kg/ha and 1885 kg/ha following the Cav-only and the MP ley treatments respectively. A comparison of yields between the Cav-only and the MP for each SR is given in Fig. 11.a-c below.

1999/2000

Sowing sorghum into Sabi dominated paddocks in the early Wet season caused some variability in sorghum establishment, consistent with previous seasons. This was due to the toughness of the crowns of established plants and the lack of penetration by the planting coulters.

Sorghum was sown no-till into Paddocks 1-6 following two years of ley pasture, which was the second occasion of a full 3-year rotation for these paddocks. Paddock 1 (MP, Medium SR) was used to trial herbicide treatments and planting strategies to address specific issues identified in previous seasons, so yield results are difficult to compare with the other paddocks.

The average yield across the SRs (L, M, H) was 1627 kg/ha and 1333 kg/ha following the Cav-only and the MP ley treatments respectively. A comparison of yields between the Cav-only and the MP for each SR is given in Fig. 11.a-c below.

Yields were lower than the previous year and reflected the poor establishment due to bird damage of seedlings and the significant bird damage to the grain before harvest. These yields would be significantly improved with good plant populations at establishment and no birds after the sorghum comes into head.

2000/2001

Sorghum was sown no-till on paddocks 7-12 following two years of ley pasture.

The average yield across the SRs (L, M, H) was 1733 kg/ha and 2000 kg/ha following the Cav-only and the MP ley treatments respectively. A comparison of yields between the Cav-only and the MP for each SR is given in Figure 11.a-c below. Bird damage was a significant issue, with an estimated 50% reduction in yield attributed to bird consumption of grain prior to harvest.

Paddock 19 is continuous sorghum cropping with 50% conventionally tilled and 50% no-tilled. There was little difference between the CT and NT yield, even though the NT area had a dense infestation of AMG.

2001/2002

Sorghum was grown no-till in paddocks 13-18 following two years of ley pasture.

Unique to this season, the sorghum was established as a variety trial, with 13 varieties replicated five times, each with a plot size of 100m x 3m. Glyphosate was applied as a knockdown herbicide in November prior to no-till sowing on the 18 December using the 8-row Mason planter. A compound fertiliser (16-18-0-12 + TE) at 180 kg/ha was applied at sowing. Urea (90 kg/ha) and Muriate of Potash (90kg/ha) were top-dressed on 22 December.

Post-plant pre-emergent herbicides (Atrazine 500® at 2 L/ha and Dual Gold® at 1.5L/ha) were applied by boom spray on 20 December for the control of various grasses and broad leaf weeds.

The variety trial required more measurements compared to bulk area planting, including plant population, insect and pest occurrence, plant height, head type, resistance to head mould and leaf disease, plant lodging, flowering and maturing dates, and hand-harvested yields. Results are provided in Table 3.

Machine harvest paddock yields (across varieties) are shown in Fig. 11. Paddock 19 is continuous sorghum cropping with 50% conventionally tilled and 50% zero-tilled.

The average yield across the SRs (L, M, H) was 3567 kg/ha and 3033 kg/ha following the Cav-only and the MP ley treatments respectively. A comparison of yields between the Cav-only and the MP for each SR is given in Fig. 11 below.

Yields were the highest this season since the trial's commencement. This reflects the better establishment of the sorghum (Mason planter) compared with most previous years.

Bird damage to grain late in the season was heavy, consistent with all previous seasons. However, production in a sacrifice area in a nearby paddock, which was not equipped with scare devices, was reduced to @1000 kg/ha, indicating the potential loss in the LFST crop.

The CT section of paddock 19 was re-sown after a heavy downpour of rain on the same day as planting. The replanted population turned out to be a little too high. The no-till area had a high infestation of AMG, consistent with the previous season, but this did not result in a yield difference.

Table 3*. Sorghum variety trial data from LFST paddocks. Extracted from Technical Annual Report No.304.2001/02. P58.*

Sorghum variety trial 2001 -2002												
Systems paddocks 13 to 17 Douglas Daly Research Farm												
Seed company	Sorghum variety	Average first flower DAP	Average 50% flower DAP	Average head type (O,SO,SC, C)	Average height	Average head mould	Average head exert	Average lodging 1 to 5	Average leaf disease	Average plant population	Average HHY at 13% moisture	Krondomic weight
Pioneer	85G83	62	67	SC	1.3	3	1	5	3	64,700	4,324	77.5
Pacific	Buster	56	62	SO	1.3	3	3	5	3	95,700	4,970	78.5
Pacific	Maxi	56	62	SO	1.4	4	4	5	3	119,700	5,282	78.0
Pioneer	82G55	67	71	C	1.7	3	2	5	4	63,900	4,772	79.0
Pioneer	8118	63	69	SO	1.5	4	3	5	3	88,800	5,537	83.0
Pacific	Pacer	55	60	O	1.3	3	3	5	2	111,300	4,646	76.5
Pacific	MR43	59	63	O	1.3	3	2	5	3	103,800	5,629	78.5
Pioneer	Graze N Sile	65	69	C	2.1	4	3	4	3	83,300	6,477	81.5
Pioneer	Jackpot	61	65	C	1.4	3	4	5	4	67,300	4,939	78.0
Pacific	MR32	51	56	SO	1.3	3	3	5	2	93,300	4,494	81.0
Pacific	Chopper	65	71	C	1.9	4	2	4	3	31,900	3,340	81.0
Pioneer	Bonus	65	69	SC	1.4	4	3	5	4	79,200	5,599	80.0
Pioneer	8586	61	65	C	1.3	3	2	5	3	78,200	4,935	81.0

Head Type

O = Open
SO = Semi open
SC = Semi closed
C = Closed

Lodge

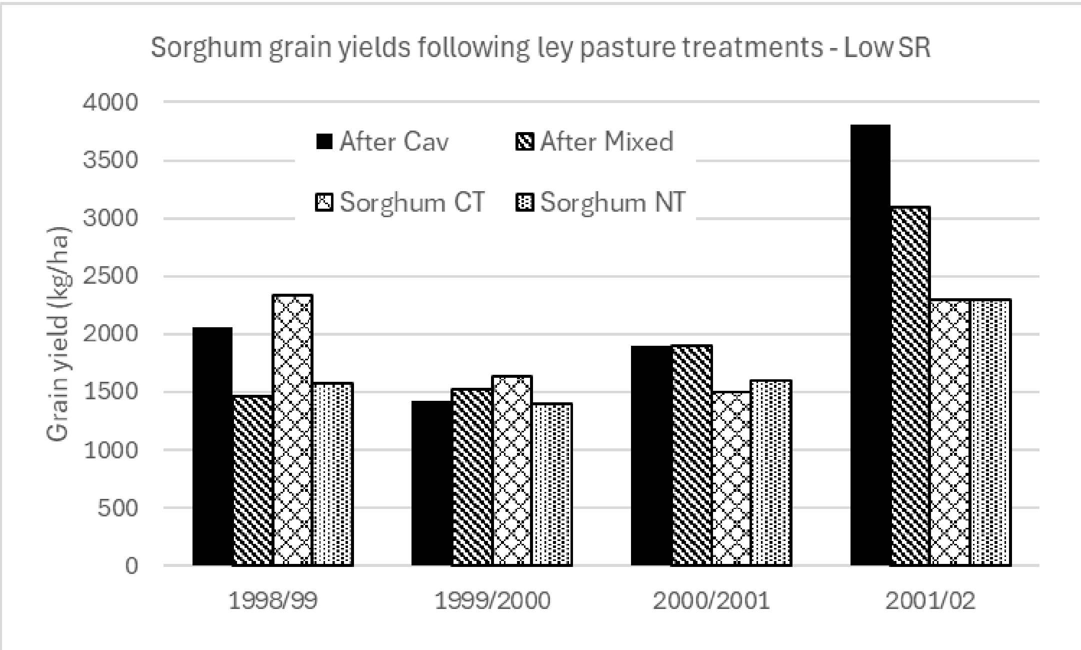
1 = Severe lodging
5 = No lodging
DAP = Days after planting
HHY = Hand harvested yield

Head Exertion

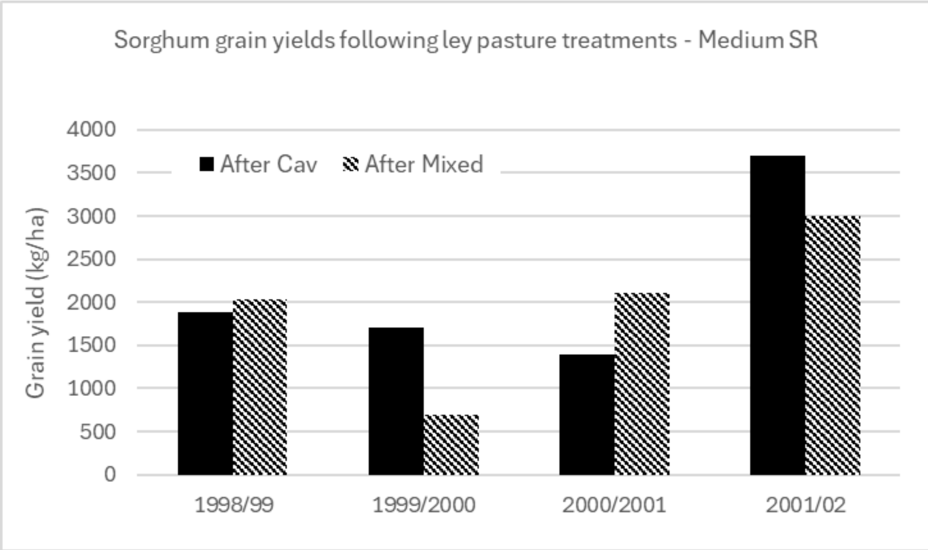
1 = Poor exertion
5 = Good exertion

Leaf Disease

1 = Severe leaf disease
5 = No leaf disease



a)



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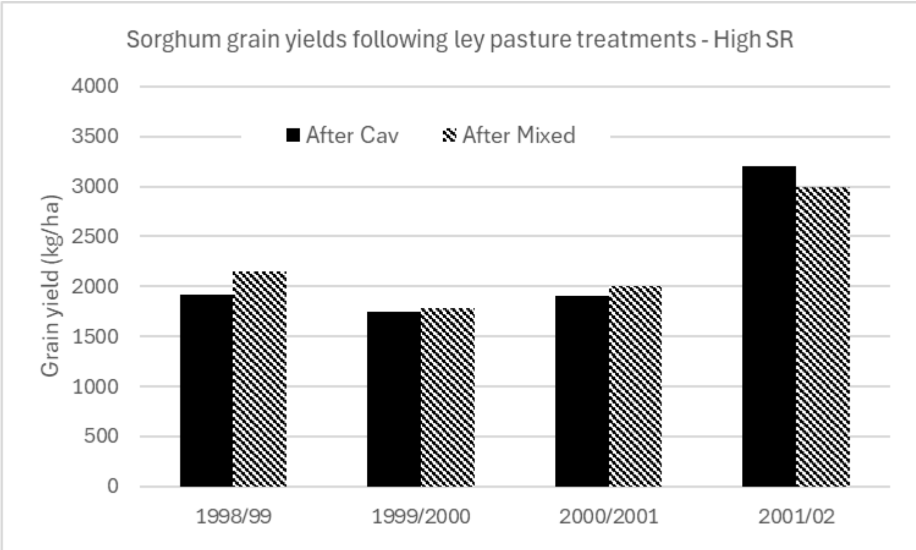


c)

Figure 11*. Sorghum grain yields across years at each of the SR treatments a) Low, including the continuous sorghum paddock, CT (conventional till) and NT (no-till); b) Medium, and c) High.*

Conclusion

There did not appear to be a SR effect on sorghum grain yield, although this was not statistically determined. Data was presented here for each SR treatment for ease of interpretation of year and ley pasture treatment effects. There was variability between years, with the 2001/02 average yields (3567 and 3033 kg/ha following Cav-only and MP respectively) the best achieved across the LFST. This was the year a variety trial was conducted, with better crop establishment and use of a nearby area as a ‘sacrifice’ crop for bird damage.

The sorghum following the Cav-only pastures generally had higher average yields across SRs compared to the MP across seasons This is probably due to a combination of increased nitrogen contribution from the Cavalcade, less AMG from use of selective herbicides in Cavalcade, and generally better sorghum populations due to easier planting into the Cavalcade mulch.

The two key confounding factors in comparing grain crop yields were variability in crop establishment, and bird damage (see Photo 9). Further analysis would be required for a more rigorous conclusion on the effect of ley pasture treatment rotation on grain yield.

Photo 9. *Bird damage was a significant factor on variable sorghum grain yields.*

Cattle Production

Introduction

Cattle production in northern Australia was historically based on native extensive pastures (rangelands). Cattle liveweight (LWT) trends are traditionally characterised by weight loss in the late Dry and early Wet seasons followed by rapid and often compensatory growth in the Wet and early Dry seasons (Fig. 12). The higher rainfall areas of the 'Top End' have enabled the adoption of improved pastures to contribute to increased cattle productivity.

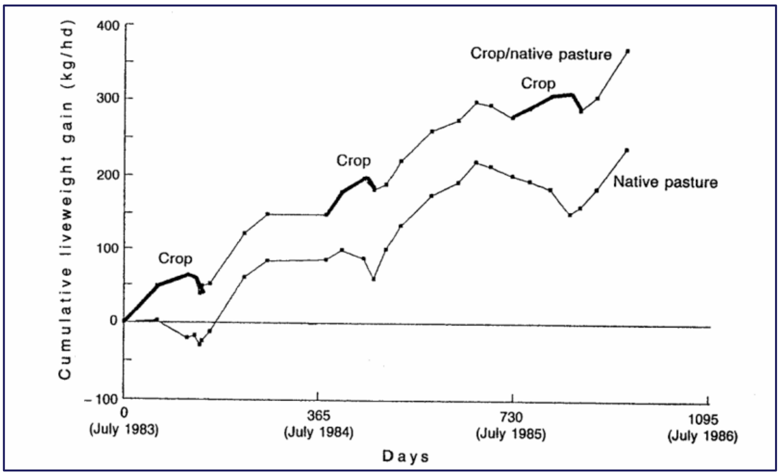


***Figure 12**. Cumulative liveweight trends for cattle either continuously on native grass pasture (thin lines) or on croplands (thick lines) in the main dry season and on native grass pasture for the rest of the year (sourced from M^c^Cown et al. 1986).*

The impetus for the cattle production component in the LFST was supported by a strong live export market for young high grade Brahman cattle weighing up to 350kg, and previous studies which had shown that grazing crop residues at conservative stocking rates produced liveweight gains of up to 900 g/hd/day throughout the Dry season (Austin *et al.* 1988).

The LFST aimed to evaluate practices to maintain liveweight over the Dry season and arrest the late season liveweight loss to improve breeder and export enterprises efficiencies.

Strategies used to address these issues included:

- Develop a grazing management system for animal production using a pasture legume ley / crop no-till system.
- Monitor pasture condition, composition and persistence under various grazing pressures.
- Assess animal performance under different stocking rates.
- Link and validate pasture and livestock parameters to existing models to allow simulation of grazing scenarios.
- Estimate optimal grazing pressure to ensure sustainability and productivity.

The improvement in cattle productivity could also contribute to reducing GHG emissions. This is a current priority of cattle production in Australia, with a key measure of success including establishment of new legume-based plantings (Industry GHG emissions avoidance | Meat & Livestock Australia). This was not considered in the initial rationale of the LFST, but the use of higher quality pastures in the Top End can assist in improving cattle productivity with a subsequent reduction in methane emissions from cattle enteric formation (O'Gara & Eastick, 2024).

Method

Cattle production was assessed in the Ley Farming System Trial paddocks at DDRF from 1994 to 2002. Liveweight gain of weaners and/or yearling cattle was compared on ley pasture treatments of either 1st year pasture, 2nd year pasture, or sorghum stubble following the 2nd year pasture.

The ley pasture species was divided into two main plot treatments, either a pure legume (Cavalcade only), or a legume-grass mix (Cavalcade / Sabi grass), termed mixed pasture (MP). Each main plot pasture treatment was 14 hectares, comprised of three paddocks: a 6-hectare and two 4-hectare paddocks. These paddocks were grazed at three stocking rates categorised as Low, Medium and High (L, M, H). This represented the split-plot treatment within each of the ley pasture main treatments (Cav-only versus MP) for comparison of cattle liveweight gains.

The actual rate in head/ha or kg/ha was determined by the initial liveweight of the weaners introduced into the trial, and condition of the paddocks to be stocked. Initial LWT was stratified to enable a representative distribution of weaners into each treatment paddock. Introduction of cattle onto the treatment paddocks aimed to correspond with the main weaning round - usually around late April/early May. This enabled assessment of weight gain over the Dry season on saved improved pastures or sorghum stubble.

Consistent metrics were not available for all years, but Table 4 shows the date when cattle were introduced into the treatment paddocks, number of Dry season days grazed, and stocking rates (SRs). Cattle were weighed every four weeks after introduction onto LFST paddocks (monthly data not presented). Final cattle weights were collected when the paddocks were destocked.

Cattle husbandry practices included treatment for parasites (Ivomectin), Botulism and 5-in-1. All paddocks were supplemented - initially with Weanermaster® & Rumensin® in the Dry season, and Phosrite® in the Wet season. Metrics for supplement consumption were recorded at each time of cattle weighing, but data was not collated for this report.

Table 4. *The allocation of liveweight (LWT) per paddock for the stocking rate (SR) treatments, and grazing dates across years for the Dry season grazing (not all data available). Crash grazing for mulch management and Wet season grazing periods not included. *Weaners and yearlings used.*

Year	SR	No. of Head	SR (hd/ha)	Total LWT / paddock (kg)	LWT / Ha (kg)	Date In	No. of days
1996	L	6	1			14 Aug	90
	M	8	2				
	H	12	3				
1997	L	6	1	942	157	5 June	112
	M	8	2	1256	314		
	H	12	3	1884	471		
1998	L	6	1	1110	185	1 June	143
	M	7	1.75	1295	324		
	H	9	2.25	1665	416		
1999*	L	6	1	1170	195	17 June	120
	M	7	1.75	1365	341		
	H	9	2.25	1755	439		
2000*	L	6	1			22 June	120
	M	7	1.75				
	H	9	2.25				
	L	6	1			5 June	140

2001*	M	7	1.75		
	H	9	2.25		
	L	6	1		
2002*	M	7	1.75	12 June	na
	H	9	2.25		

Results and Discussion

One of the main aims of the LFST was to assess Dry season grazing of ley pastures to increase cattle productivity.

Cattle management varied across seasons, influenced by seasonal conditions such as time of commencement of the Wet season, requirements for crash grazing to manage biomass levels prior to sowing no-till sorghum, and Wet season pasture utilisation. Although cattle were weighed monthly throughout the duration of the Dry season grazing, this data was not collated for this report. (This data was subsequently located in the Archives room at DDRF). Cattle production is discussed below for each season, with data generally for total Dry season liveweight gains.

1996 Dry season and 1996/97 Wet season

Weaners were obtained from mixed lots originating in QLD. Average weight was 157 kg/hd when the weaners were introduced onto the treatment paddocks on 14 August 1996. This was later than desirable, due to difficulties with obtaining weaners.

Figure 13 summarises the cattle liveweight (LWT) gains (kg/hd) from that time to when they were removed from the trial paddocks in November (@90 days). Values are presented for the Low, Medium and High Stocking rates (L, M & H) for the 1st and 2nd year ley pasture treatments (Cav-only and MP), and the sorghum stubble (SS) paddocks, following the two ley pasture treatments. LWT gains on a per hectare basis can be derived by multiplying kg/hd by SR (e.g. 1, 2 or 3 hd/ha).

There was a stocking rate effect (not analysed) with the Low SR producing the best LWT gain (kg/hd) in all grazing treatments, except for the 1styear Cav-only. This discrepancy may have been due to the high weed burden in this paddock.

Weight gain at the Low SR ranged from 150 g/day/hd for the 1st -year Cav-only to 440 g/day/hd for the sorghum stubble for the 90-day Dry season grazing period. For the similar period at the High SR, weight gains ranged from 10g/day/hd for the 2nd year Cav-only to the highest gain on sorghum stubble of 31 g/day/hd.

The high stocking rate resulted in the greatest weight gain on a kg per hectare basis for the Dry season grazing period. Gains ranged from 26.5 kg/ha for the 2ndyear Cav-only to 83.5 kg/ha on the sorghum stubble. However, it was the deterioration of the high stocking rate paddocks which determined that all LFST paddocks were destocked by mid-November, and cattle moved onto other improved pastures on DDRF (Fig. 14).

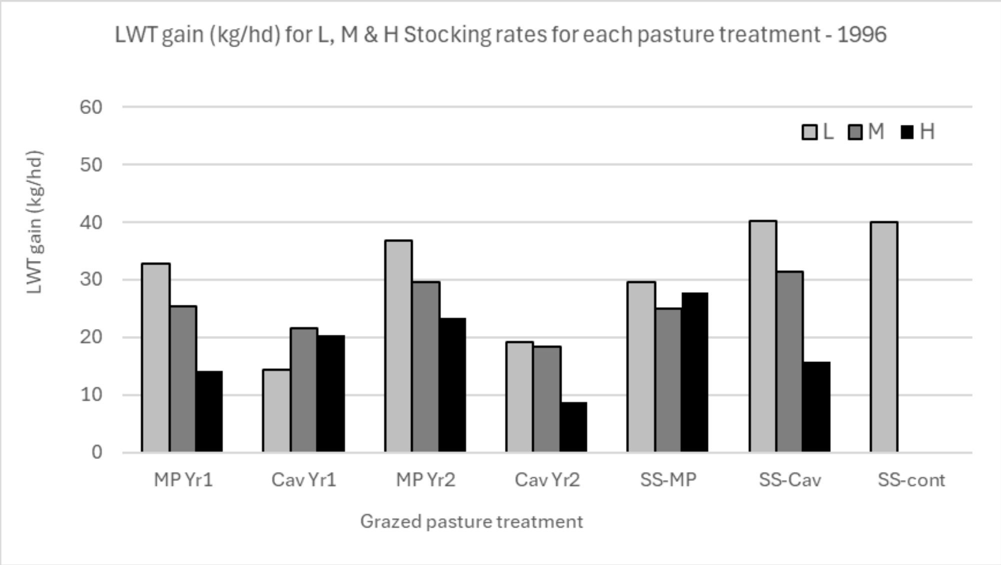


***Figure 13**. Weaner LWT gains for each SR (L, M, H) for each grazed pasture treatment for 1996 Dry season (@90days).*

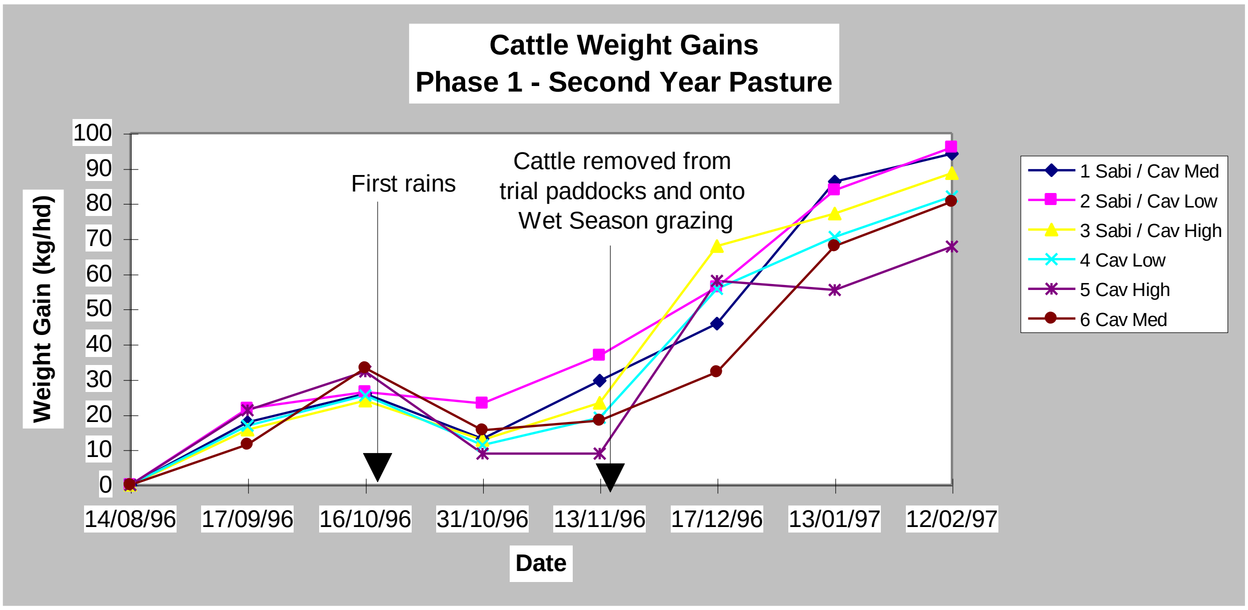


***Figure 14**. Weight gain trends for 2nd year ley pasture treatments, showing the change in pasture dynamics with the onset of the first rains. Cattle weight gains declined rapidly in the Cav-only H SR (paddock No.5) with standing biomass deteriorating after rain. (Source: historical internal report).*

1997 Dry season and 1997/98 Wet season

140 weaners for the LFST were drafted from a mob of Tipperary Station weaners. These arrived at DDRF on 30 April with average weight 185.7 kg (Photo 10). They were castrated, branded, inoculated, dehorned and ear-tagged, then grazed a Buffel grass paddock until allocated to their respective treatment paddocks on 5 June 1997.

Cattle were mustered and weighed from all treatment paddocks every four weeks from 5 June – 25 September for assessment of Dry season liveweight production. All paddocks were stocked from June to September (112 days). The paddocks at the high stocking rates generally determined when the LFST paddocks had to be de-stocked due to depletion of feed. The Cav-only pastures which 'collapsed' at the break of the season were de-stocked by early October.

Other paddocks remained stocked depending on feed availability, with all cattle finally removed by December 1997. Paddocks to be sown to sorghum were crash grazed to reduce mulch levels by cattle that had been removed from the treatment paddocks.

Photo 10*. Weaners at DDRF on the 30 April 1997 prior to allocation into treatment paddocks on 5 June 1997.*

There was a stocking rate effect (not analysed), with the best weight gains (kg/hd) from the low stocking rates across most grazing treatments (Fig. 15). The LWT gain ranged from 150 g/hd/day on the 2nd -year MP High SR to 503 g/day/hd at the Low SR for the sorghum stubble following Cav-only treatment.

LFST pastures establishing into their 2nd season were stocked at 1 head/ha until February to better utilise pastures over the Wet season, after which they were removed to allow pasture species to set seed and recover biomass prior to the forthcoming Dry season grazing period. This was more practical and realistic than leaving unstocked as had happened in the previous year. Cattle were grazed on Sabi / native pasture mix over the remaining Wet season, and eventually onto Coastal Plains Research Farm prior to sale.

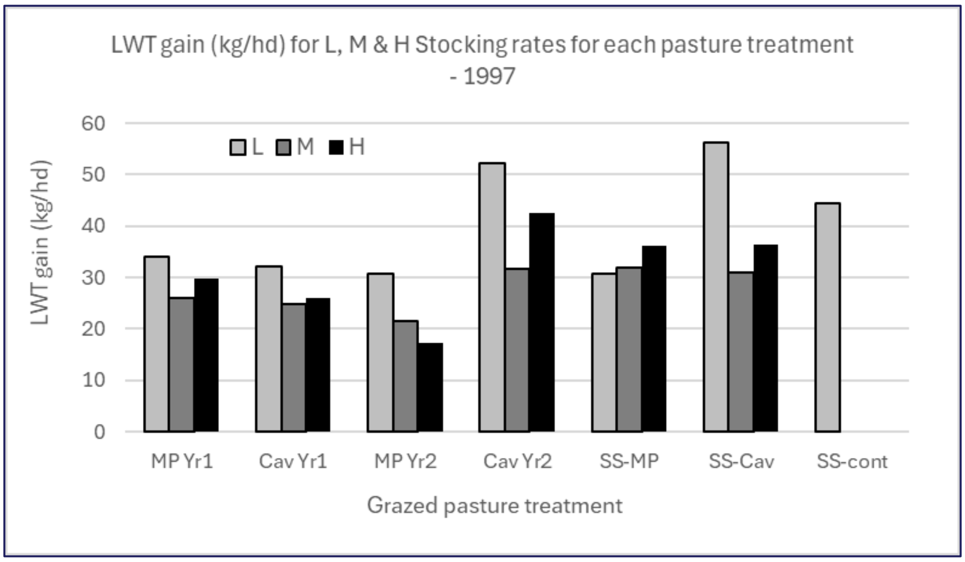


Figure 15*. Weaner LWT gains for each SR (L, M, H) for each grazed pasture treatment for 1997 Dry season (@112 days).*

1998 Dry season and 1998/99 Wet season

Weaners were allocated into their treatment paddocks on 1 June 1998, stocked until 21 October for the Dry season grazing period (143 days). Some areas of all paddocks were inundated for a long period after the January ’98 flood, with high mortality of sorghum and pastures in lower lying areas. However, Sabi and Cavalcade both regenerated quickly (see 1997/98 Pasture Production section), producing good biomass by May (refer Fig. 6). It is unclear why the cattle weight gains were relatively poor (Fig. 16), but this may have been associated with the flood effects.

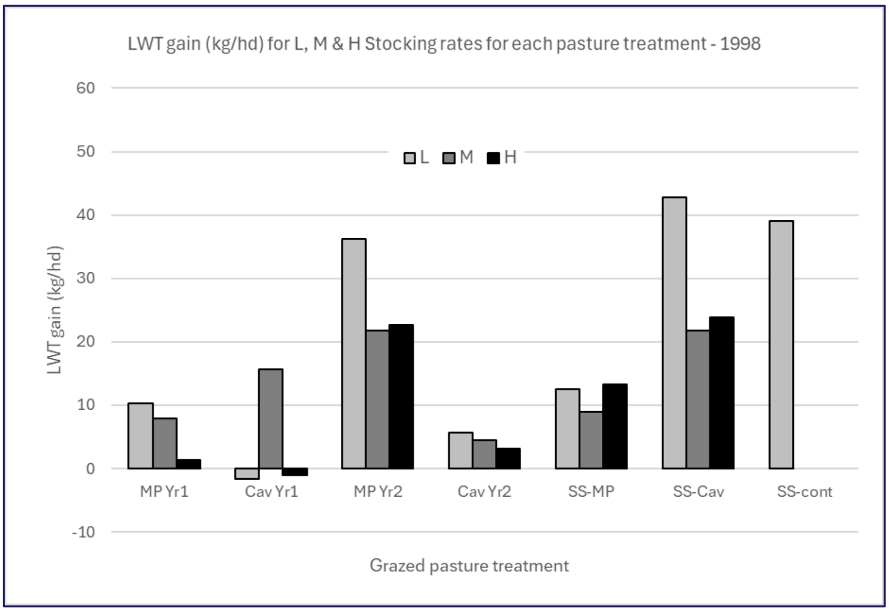


Figure 16. Weaner LWT gains for each SR (L, M, H) for each grazed pasture treatment for 1998 Dry season (@143 days).

1999 Dry Season

Weaners were allocated into their treatment paddocks on 17 June 1999, with all paddocks stocked until end-October. The LWT gains across treatments are shown in Fig. 17, with the sorghum stubble pastures providing LWT gains up to 430 g/hd/day at the Low SR. There were some inconsistencies with the SR effect. The relatively poor LWT gains for the 2nd -year MP may be due to the lack of Cavalcade in the pasture mix (refer Fig. 8b).

Groups on the mixed pastures continuously grazed these paddocks until 22 March, after which all paddocks remained de-stocked until new weaners and the smallest of the previous season's yearlings were restocked on 22/06/2000. The other paddocks were destocked and used as mulch removers in paddocks that needed to be sown to sorghum. This generally reduced weight gains in cattle where mainly summer grass was grazed at heavy stocking rates (data not provided).

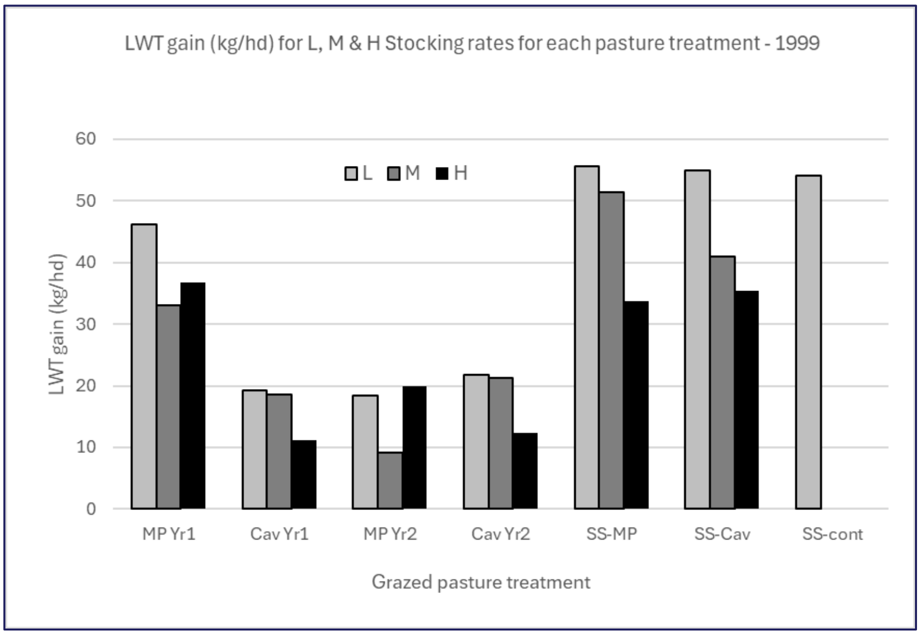


Figure 17. *Weaner LWT gains for each SR (L, M, H) for each grazed pasture treatment for 1999 Dry season (@130 days).*

2000 Dry season and 2000/01 Wet season

Weaners and the 38 smallest of the previous year's group (yearlings) were allocated into their treatment paddocks on 22 June 2000, stocked until 12 October (@120 days). Liveweight gains for this period are shown in Fig. 18.a,b. Results are presented separately for the weaners and yearlings. There was a stocking rate effect (not analysed) for most of the grazing treatments for both the weaners and the yearlings.

Sabi and Cavalcade regenerated well from the seed bank after the sorghum phase (paddocks 1-6). The 1st year Cav-only paddocks had a high weed burden, so a knockdown herbicide was applied and Cavalcade resown with a post-plant pre-emergent application of Spinnaker®. Well established Cavalcade with minimal weed competition (data not available) may have contributed to the high LWT gains for these grazed pasture treatments.

Groups on MP paddocks grazed continuously into the 2000/01 Wet season, from 12 October 2000 until 28 March 2001. Liveweight gains for this period were 99.5, 56.5, 28 kg/hd for the L, M and H SRs respectively on the 1st-year MP treatment, and 105.8 and 114.5 kg/hd for the L and H SRs on the sorghum stubble following MP.

Groups from other pasture treatments were used as 'mulch removers' in paddocks that needed to be sown to sorghum. This generally reduced weight gains in cattle (data not available) where mainly annual summer grasses were grazed at heavy stocking rates to reduce biomass. All paddocks then remained de-stocked until the 2001 Dry season grazing treatments commenced.

Cattle were turned off during March to go for export. However, the 38 lightest cattle were retained for restocking during the 2001 Dry season. This aimed to gather further data on getting heavier growing cattle up to higher turn-off market weights over a second Dry season.

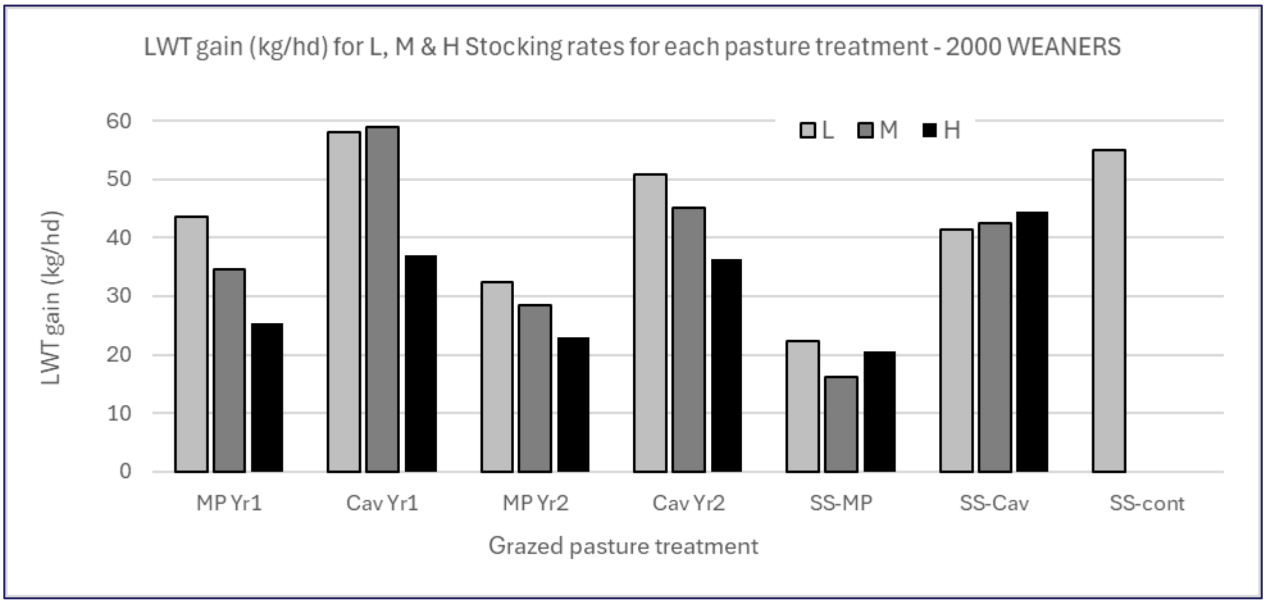


Figure 18.a *Weaner LWT gains for each SR (L, M, H) for each grazed pasture treatment for 2000 Dry season (@120 days).*

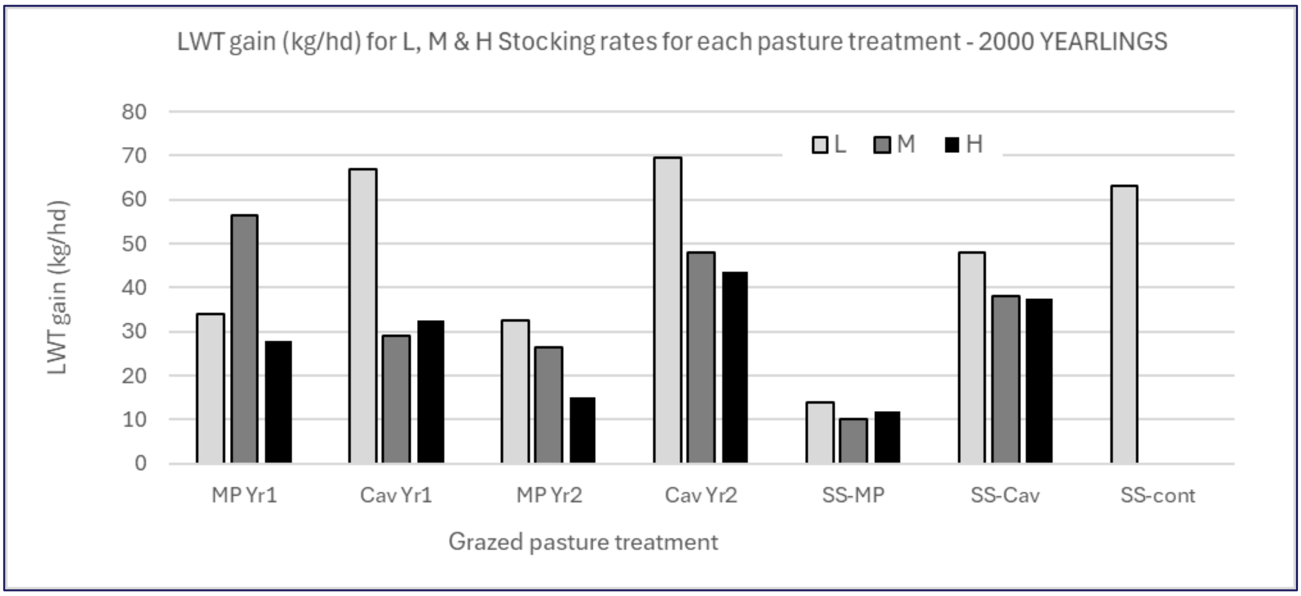


Figure 18.b *Yearling LWT gains for each SR (L, M, H) for each grazed pasture treatment for 2000 Dry season (@120 days).*

2001 Dry season and 2001/02 Wet season

Weaner steers were introduced to the treatment paddocks on 5 June 2001 whilst the 38 in the yearling group (2000-01 weaners) were allocated to their treatment paddocks on 21 May. All ley pasture treatment paddocks were de-stocked on the 22 October 2001. Results for the weaners and yearlings are presented separately in Fig. 19. a,b below.

Cattle were used where necessary to crash graze the paddocks to be sown to sorghum over the 2001/02 wet season.

Weaners were grazed at two hd/ha in MP paddocks from 8 January until 21 March 2002, after which all paddocks remained de-stocked until the 2002 Dry season grazing was imposed. Wet season LWT gains of 48.2, 34.9 and 55.6 kg/hd were recorded in the L, M and H SR paddocks (but set-stocked at 2hd/ha) for the 1st-year MP and 37.2, 34.4 and 42.5 kg/hd in the sorghum stubble paddocks following MP.

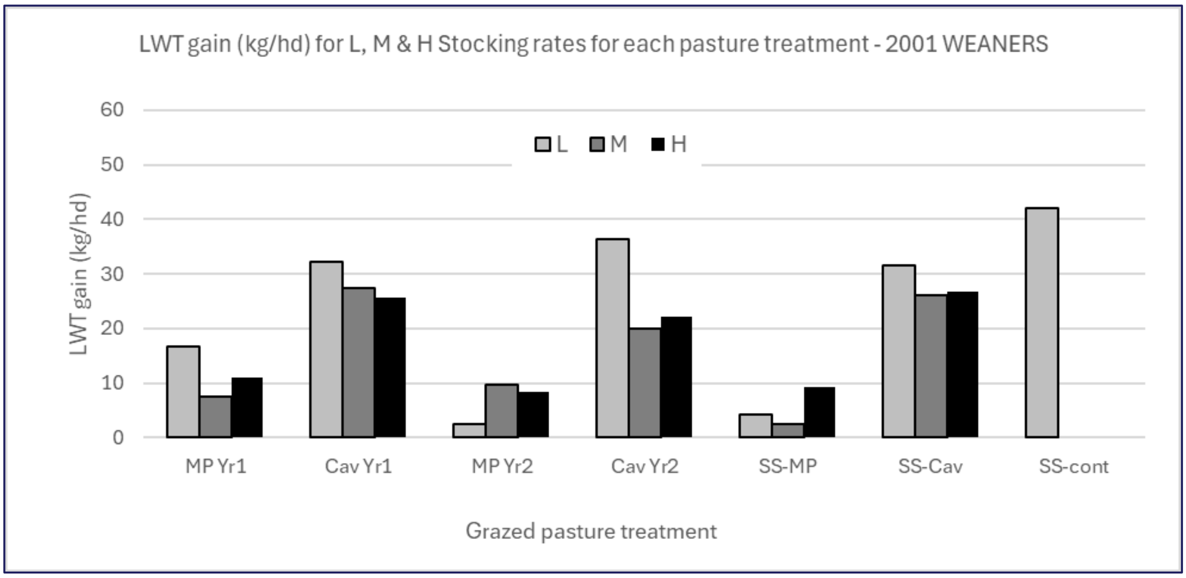


Figure 19.a *Weaner LWT gains for each SR (L, M, H) for each grazed pasture treatment for 2001 Dry season (@140 days).*

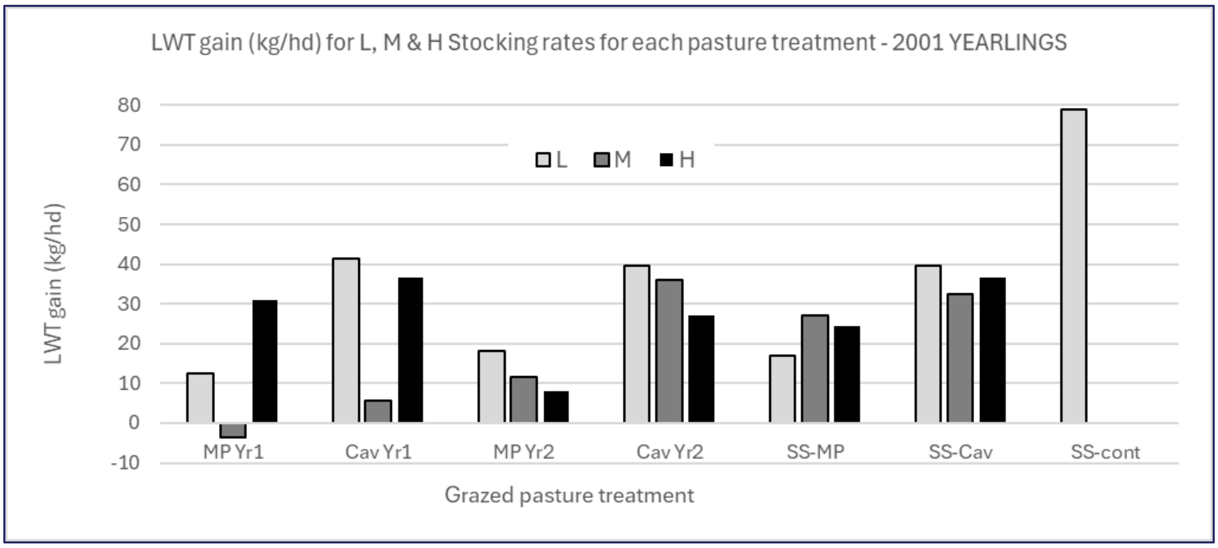


Figure 19.b *Yearling LWT gains for each SR (L, M, H) for each grazed pasture treatment for 2001 Dry season (@140 days).*

2002 Dry season

The 38 lightest cattle from the previous season's yearlings were restocked on 23 May 2002. The new batch of weaner steers from Tipperary was introduced to paddocks on 12 June 2002.

No further details were found to present in this report. This was the final year of the LFST.

Conclusion

Seasonal differences will obviously influence pasture dynamics and cattle liveweight gain. However, Stocking Rate effects within each season on the cattle LWT gains were consistent within the two different ley pasture treatments with higher liveweight gain at lower stocking rates in each year. The sections above presented the annual results. Fig. 20.a,b below illustrates differences across years, and different trends within years between the two ley pasture treatments (Cav-only and MP).

The effect of ley pasture treatment on cattle weight gain was inconsistent across seasons. The 2nd year pasture treatment appeared to have more marked trends compared to the 1st year pastures. Weight gains in the MP treatment were higher than the Cav-only treatments across the three SRs in 1997, 2000 and 2001 for the 2nd year pastures. This may be due to carryover stocking rate effects from the 1st year grazing period, including perennial grass competition and selective grazing which reduces the proportion of legume in the pasture mix.

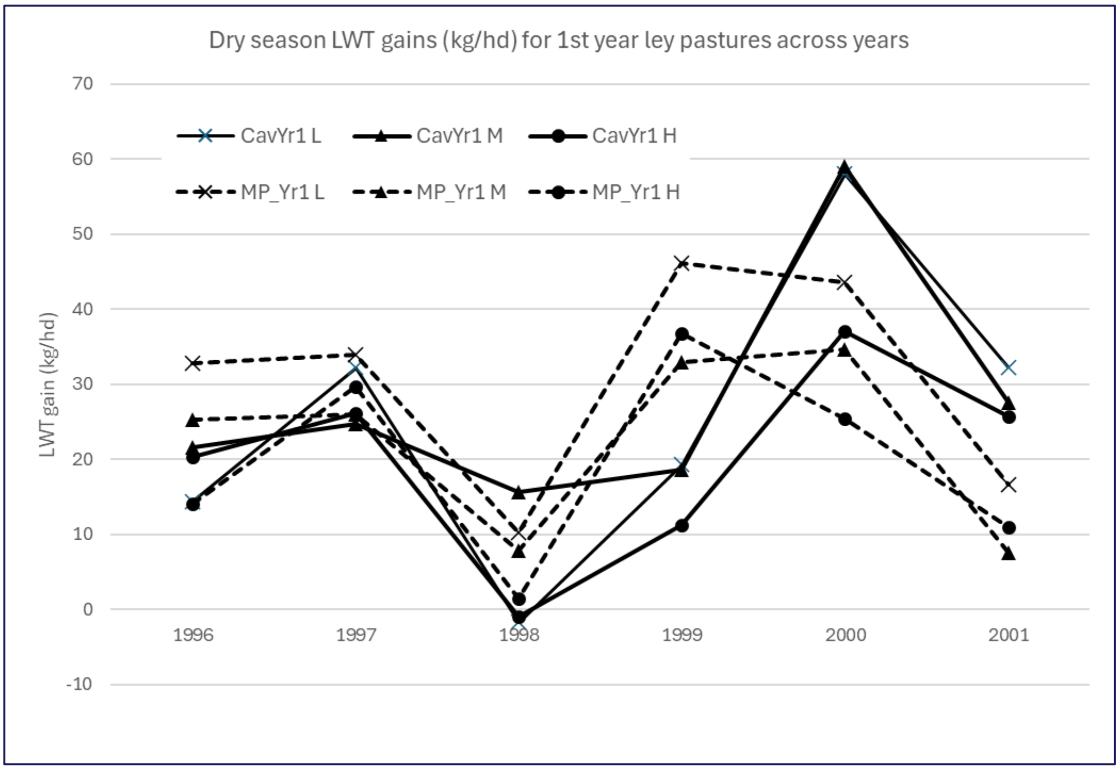
The trends for lower weight gains across 1998 are likely due to the extraordinary Wet season. This contributed to the inundation of some paddocks of pastures and sorghum in the January 1998 floods, with subsequent changes in pasture and weed dynamics (e.g. as illustrated in Photos 1 and 2). Although biomass yields in May were not markedly lower for 1st year pastures and were substantially higher for the 2nd year pastures compared to other seasons, rapid biomass production and high rainfall and nutrient leaching conditions could potentially dilute nitrogen and phosphorus content of the pastures. A reduction in pasture quality (not quantified) would contribute to lower cattle liveweight gains.

Generally, the Low SR consistently resulted in the highest LWT gains (kg/hd) compared to the Medium and High SRs, within the Cav-only and the MP treatments, both 1st year and 2nd year pastures, irrespective of year. This was not unexpected.

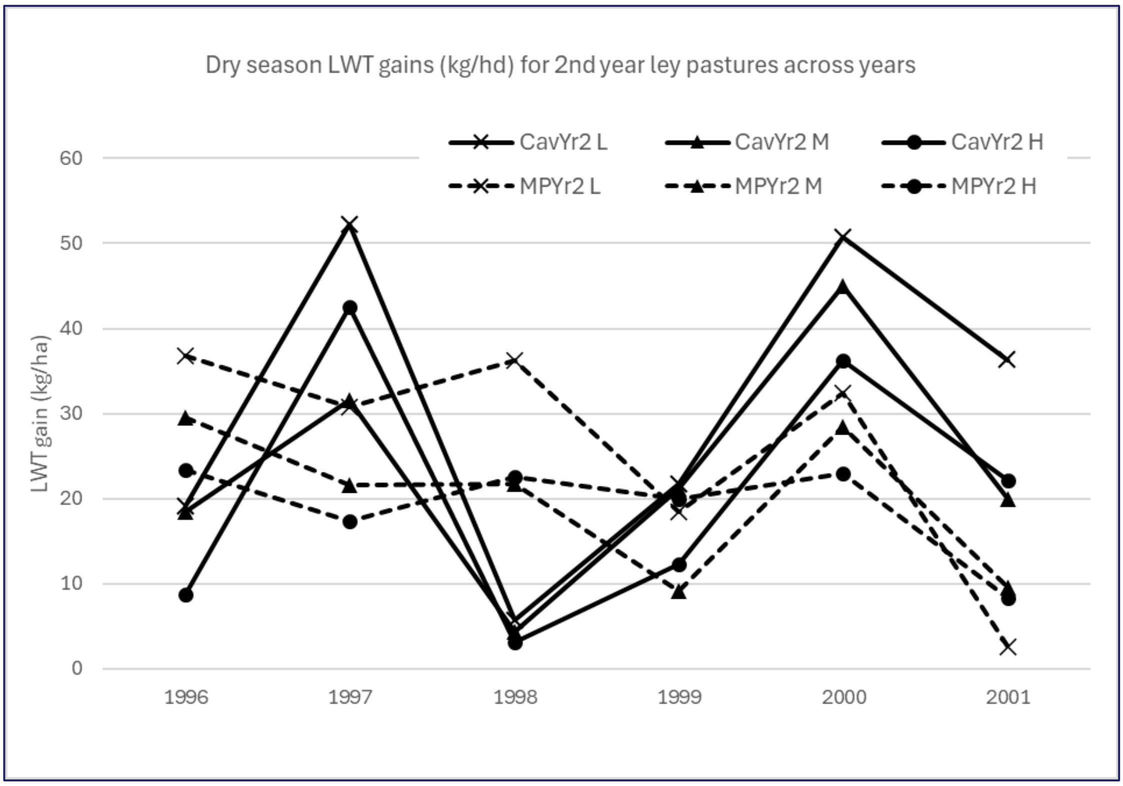
Acknowledging variability, and excluding the 1998 flood year results, the average LWT gain on 1st year ley pastures across years (1996-2001, excluding 1998) for the Cav-only was 31.24, 30.28 and 24.06 kg/head and for the MP was 34.62, 25.3 and 23.4 for the Low, Medium and High SRs respectively. The average LWT gain on 2nd year pastures across years (1996-2001, excluding 1998) for the Cav-only was 36.02, 27.24 and 24.44 kg/head and for the MP was 24.20, 19.66 and 18.4 kg/ha for the Low, Medium and High SRs respectively.

Cattle weight gains on sorghum stubble following Cav-only compared to MP across the three stocking rates were higher in 2000 and 2001 (Fig. 21). There was variability in other years. The average LWT gain across years (1996-2001) was 44.53, 32.22 and 30.38 kg/head following Cav-only and 25.83, 22.65 and 23.48 kg/head following MP for the Low, Medium and High SRs respectively.

Cattle weight gains between different pasture treatments, and different stocking rates across different seasons is a complex dynamic. More detailed statistical analysis would be beneficial to further explore significant effects.



a)



b)

***Figure 20. a,b**. Cattle Dry season liveweight gains (kg/hd) by ley pasture treatment (Cav-only, Mixed Pasture) and SR (L, M, H) across years of LFST.*

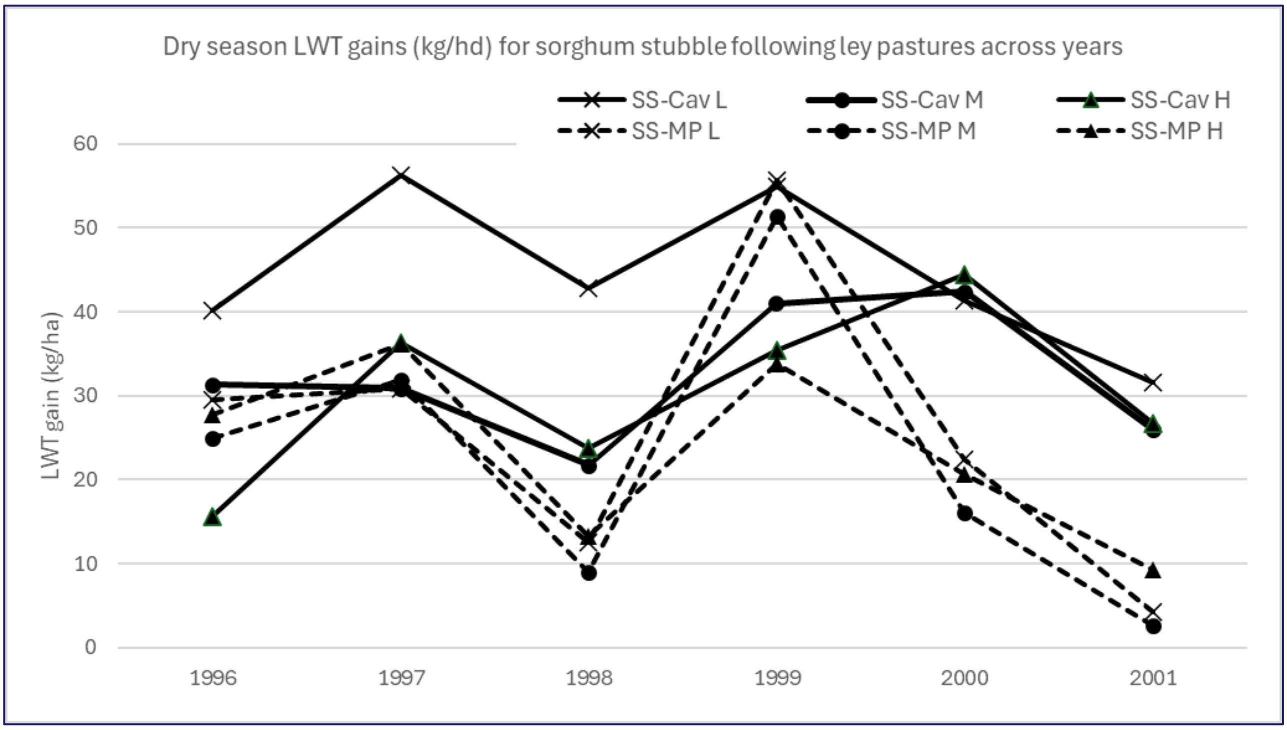


***Figure 21**. Cattle Dry season liveweight gains (kg/hd) grazing sorghum stubble following two ley pasture treatments (Cav-only, Mixed Pasture) and SR (L, M, H) across years of LFST.*

Weed Management

Introduction

A cereal grain crop, a legume pasture, and a mixed legume-grass pasture, each have their own weed dynamics and weed control options. Incorporation of grazing into these enterprises confounds these weed dynamics through processes such as selective grazing, soil disturbance and removal of soil cover, and nutrient cycling.

A ley farming system incorporating grazing on either a mixed legume-grass pasture or a legume only pasture phase in rotation with a no-till cereal grain crop aimed to provide several advantages for weed control. Benefits were considered to include:

- Ability to use a grass-selective and / or broad-spectrum selective herbicide in the Cavalcade phase to control prevalent agricultural weeds in northern Australia including annual mission grass (*Cenchrus pedicellatus*, previously *Pennisetum pedicellatum*), sicklepod (*Senna obtusifolia*), Hyptis (*Hyptis suaveolens*) and Sida species (e.g. *S. acuta* and *S. cordifolia*).
- Ability to use a selective herbicide in the Sorghum crop phase to eliminate weeds which have persisted through the two-year grazing phase, especially in the mixed pasture which has limited options for herbicide control.
- Inhibition of weed seed germination using no-till versus conventional till sowing methods.
- Strategic grazing enabled an integrated option to manage weed populations.

Method

Weed species were recorded as part of the pasture composition assessments in May and November each season, discussed in the Pasture Production section previously. The May assessment represented the weed burden forming part of the grazed pasture for the Dry season grazing period. The November assessment indicated the effect of grazing on changes in weed populations.

There was no prescribed method for weed management. Weed management decisions in any agricultural system are rarely prescriptive. Numerous factors effect weed control options. The most basic is weed species present, and any requirement to minimise damage to desirable species.

Herbicide options are limited in mixed pastures, are limited in Cavalcade for legume weeds such as sicklepod, and can be variable in cereal crops, especially no-till where mulch can interact with herbicide efficacy. Weather conditions and soil type can further confound herbicide options.

Grazing management was used to manipulate weed dynamics. This varied according to species composition and time of season.

Results and Discussion

Species composition data showing changes in weed population was available for the initial years of the LFST (1995-1998) but was unavailable after that period. Data is interpreted below where available, otherwise general comments about weed dynamics and trends are provided.

Table 5 shows an example (1996) of the change in pasture species composition of Sabi, Cavalcade, broadleaf weeds and AMG from May to November across ley pasture and crop grazing treatments. It is difficult to conclusively determine ley pasture treatment effects on the weed populations, but data indicates several effects worth noting. Firstly, broadleaf weeds and AMG were starting to be major components of the Cav-only pastures (1st and 2nd year) at the end of the second Dry season grazing period, irrespective of SR. Secondly, the 2nd-year MP appeared to have minimal weed populations, indicative of maintaining a robust and competitive pasture. Thirdly, AMG was the dominant weed in the sorghum crop, irrespective of the preceding ley pasture treatment.

These effects suggest that the dramatic reduction in ground cover in the Cav-only paddocks may contribute to the increased weed populations, even though herbicide options were available. Maintaining a robust MP contributed to competition against weeds, even though herbicide options were very limited.

It is also possible that the November measurements allowed a 'lag' period between removal of the cattle at the end of the Dry season, and subsequent emergence of AMG (and other weeds), without grazing contributing to AMG control. For example, there was no AMG recorded in Paddock 8 (Low SR, 2nd -year MP) in November 1997 (Table 5), but there is a significant population by February 1997, when cattle are used to crash graze the established AMG.

Further rigorous interpretation of weed dynamics from the available data is limited. However, general conclusions on weed management in the LFST are discussed below.

Weed populations in the Cav-only paddocks were mostly managed through application of imazethapyr (e.g. Spinnaker®, Pursuit®) as a post-plant pre-emergent herbicide, especially in the initial sowing year, when operations are managed, and timing of germination is easier to predict. This was effective in reducing grass weed germination (summer grasses, AMG), and generally reduced populations of non-legume broadleaf weeds such as pigweeds (*Portulaca oleraceae* and *Trianthema portulacastrum*), *Hyptis* and *Sida* species. However, in some years, the residual activity of imazethapyr was relatively short-lived in warm, wet conditions, and weeds established later in the season. Grass weeds were targeted in some years with grass-selective herbicides (e.g. fluazifop (Fusilade®), sethodim (Sertin®), haloxyfop (Verdict®)), but this did not appear to be consistent across seasons.

Timeliness of application was an issue some seasons, especially for the self-sown regenerating Cavalcade establishing as a 1st-year pasture post-sorghum. Cavalcade herbicide trials were conducted elsewhere in an effort to address this issue (refer Appendix 1 and 2). Timing of herbicide application in November can be difficult due to heat, wind, and lack of follow-up rain which results in stressed plants and reduced herbicide efficacy.

Early Wet season rains which occurred prior to any application of imazethapyr resulted in a germination flush of Cavalcade from hard seed in the seed bank, but often also a germination flush of broadleaf weeds including Hyptis, Sida and sicklepod. However, one of the most problematic weeds, the legume sicklepod, was not controlled with imazethapyr. Sicklepod germination is stimulated through soil disturbance, so use of no-till sowing did reduce emergence to some extent. Significant research assessing herbicide and no-till management options for sicklepod, and other weeds, was conducted at other sites in alignment with these observations from the LFST (Eastick, 2004).

Herbicide options for weed control were limited in the MP paddocks. The key was for robust establishment after sowing, especially after the sorghum phase which was generally effective in reducing weed populations.

Grazing was also used to target grass weeds. AMG was rarely a persistent problem in the Cav-only treatment (e.g. Fig. 6a,b in Pasture Production Section). Cattle appeared to seek out grasses to supplement and adapt to the legume-only diet early in the Dry season and sought any feed with decreasing legume biomass available later in the season. (Selective grass herbicide may also have been applied early in the season). Cattle were used to crash-graze established AMG (Photo 11) but this had variable results, as cattle appeared to actively seek annual summer grasses early in the Wet season in preference to AMG.

The sorghum crop enabled four key practices which reduced weed establishment. Firstly, grazing prior to sowing sorghum was primarily for no-till mulch management, but this also assisted in reducing grass weed seedbank. Cattle grazed emerging grasses at the break of the wet season. Secondly, glyphosate applied as the knockdown herbicide prior to no-till sowing effectively killed all weeds which had either persisted through the ley pasture phase or had germinated at the break of the season. Thirdly, minimising soil disturbance and retaining mulch cover using no-till sowing reduced stimulation of weed germination and emergence. Fourthly, the application of an in-crop herbicide, usually atrazine and/or metolachlor (e.g. Dual ®) applied post-plant pre-emergence, targeted all weed species.

Observations indicated that these herbicides did not provide residual weed control over the duration of the Wet season (consistent with imazethapyr), and weed establishment occurred later in the growing season. This was consistent with previous studies (Eastick, non-published data) which evaluated residual activity of atrazine on Blain soils.

Table 5*. Change in pasture species yield (Y) composition (Sabi, Cavalcade, Broadleaf weeds (BLW), and Annual Mission Grass (AMG)) from May to November 1996 across pasture and crop grazing treatments.*

Pasture/ Crop	Pasture	SR	Sabi_Y		Cav_Y		BLW_Y		AMG_Y		Total_Y	
			May	Nov	May	Nov	May	Nov	May	Nov	May	Nov
1st yr ley pasture	MP	L	855	1329	6350	264	279	1022	906	380	8467	2839
		M	1063	1105	5393	233	201	602	1574	597	8374	2619
		H	432	523	6055	0	228	0	1117	1	7863	2205
	Cav	L	0	0	7186	355	651	498	396	505	8241	1644
		M	0	0	4701	355	274	223	175	624	6235	2190
		H	0	0	7779	440	760	195	301	266	8840	1071
2nd yr ley pasture	MP	L	6782	3293	1063	131	184	110	301	0	8373	3537
		M	5315	2738	1572	221	58	54	202	15	7212	3025
		H	6782	2817	2016	110	192	45	183	0	9165	2978
	Cav	L	142	6	4513	1760	795	932	11	265	5677	2978
		M	0	7	5751	1399	865	478	140	373	6979	2343
		H	0	16	5742	948	665	391	93	189	6654	1629
Sorghum stubble	MP	L		0		0		681		1739		2722
		M		0		0		406		1303		1908
		H		0		0		429		870		1446
	Cav	L		101		0		248		1400		2018
		M		0		0		81		1318		1619
		H		0		0		174		1237		1600

Photo 11. *19th February 1997. Cattle crash grazing Paddock 8 (2nd-year MP) in an effort to reduce AMG biomass (the large dark green clumps). This aimed to reduce AMG seed set to minimise contamination of pasture for next season's sorghum crop.*

There were limited herbicide options available for broadacre application within the MP treatments. Weed control was attempted with a herbicide carpet roller with glyphosate (Photo 12) across all MP paddocks in early January 1998, with variable results. This required stocking pastures prior to treatment to graze down the desirable pasture species, ensuring the weed species could be targeted above the pasture canopy. The major January 1998 floods occurred soon after, confounding weed control results.

A more detailed study evaluating the herbicide roller was conducted in a separate trial. However, it was noted in the LFST that the main problem was the slowness of operation (45 mins per ha for 3.6m model), although there was a low Horsepower requirement compared to the slasher. Other problems included larger weeds shielding shorter ones from the carpet, different weeds require different chemicals for best control, not 100% mortality, and rainfastness can become an issue when the operation takes a relatively long time.

Photo 12. *14 January 1998. A herbicide roller was applied across all MP paddocks at the start of 1998 (e.g. Paddock No.1, MP Medium SR, illustrated here). This was a very time-consuming operation and had variable results, mostly due to differences in the height of the weeds (e.g. Hyptis) above the pasture canopy.*

Slashing was extremely effective in reducing seed set later in large annual broadleaf weeds such as Hyptis and sicklepod in Cav-only paddocks, and to a lesser extent, in MP. The stem of the plant left in the ground is shattered and, in most cases, dies (stump rarely seen alive post slashing). This method does not significantly reduce the yield of Cavalcade, particularly if slashing is targeted – 'topping' in less dense weed infestations and cutting lower in more dense weed areas. However, early matured seed may not be affected and will remain viable on the slashed trash.

Conclusion

Conducting weed control practices within the LFST was complex due to the differences in the imposed treatments, especially the two different ley pastures, confounded by the three different stocking rates. The imposed treatments caused different weed dynamics and subsequent different weed control actions, and conversely, the different weed control actions effected the pasture and grazing dynamics. This made it difficult to interpret the treatment effects on weed populations with the LFST.

The LFST stimulated a range of separate trials to evaluate specific weed treatment effects, such as interaction between herbicide and tillage ((Eastick, 2004), evaluation of herbicides for use in Cavalcade (Appendix 1) and timing of pre-Wet season herbicide application (Appendix 2). This ensured the integrity of the treatments within the LFST itself were maximised and variability by confounding factors was minimised.

There may be some discrepancy between time of Botanal ® measurement (i.e. November) and relevance to the Wet season weed populations. The November measurement was primarily intended to document residual pasture biomass from cattle grazing treatments at the end of the Dry season. Depending on the relative time of initial rains, data for weed dynamics may be inconsistent between seasons. If there was minimal rainfall prior to measurements, weed species may not be present. If substantial rainfall had occurred, weed species would be evident, and data would be recorded. E.g. Short-lived perennial weeds such as *S.acuta* may appear as dead stalks, which can reshoot after commencement of the Wet season, or annual grasses would germinate only after adequate rainfall and soil moisture. Further interrogation of seasonal variability and weed metrics (if available) could provide more rigorous conclusions on ley pasture and SR effects on weed dynamics.

Soil Health

Introduction

Incorporation of a legume-based ley pasture (either Cav-only or grass-legume MP) in a farming system was promoted as an environmentally sustainable production system for northern Australia underpinned by improvements in soil health. Benefits were considered to include:

- Increase soil nitrogen levels.
- Increase soil organic matter and build soil structure and fertility.
- Reduce soil erosion.
- Provide an environment for beneficial organisms.
- Increase soil water infiltration, improve soil moisture conditions.
- Provide a good cover of mulch, reduce soil temperature.
- Reduce use of herbicides.
- Increase crop grain protein.
- Reduce pests and diseases.

In the current agriculture climate, with the emphasis on net zero emission targets, there would be additional benefits of reduced reliance on nitrogenous fertilisers. This would reduce emission of the potent greenhouse gas (GHG) nitrous oxide and improve carbon sequestration into the farming system. The additional zero emission benefits from a cattle productivity perspective are discussed further in that section.

Soil sampling and subsequent processing was resource-intensive, but changes in soil parameters, especially nitrogen, and the contribution of improved fertility to a subsequent grain crop, was a key component of the farming system. The resource-intensive nature was evidenced by soil sampling ceasing after May 2001 once the Berrimah Soils Laboratory introduced service fees, and it was considered that adequate soils data had been provided in the initial stages of the LFST.

Method

Soil sampling coincided with the vegetation sampling, both in timing, and quadrat collection. Samples were collected approximately at the end of the Dry season/beginning of the Wet season (November), and the end of the Wet/beginning of the Dry (May). Samples were collected in each grazing split-plot treatment with a 34 mm diameter corer. Quadrats 1 and 6, 2 and 5, and sites 3 and 4 corresponding to the top, middle, and bottom of the paddock respectively, were initially separately bulked to provide three samples for analysis. This was subsequently modified, and all six samples were pooled for analysis. Samples were generally collected from 0-15 cm and 15-30 cm. Soil sampling and analysis did vary over the duration of the LFST; this is discussed in more detail in Bithell *et al.* (2013) and shown in Table 6 below.

A reduction in nitrogenous fertiliser to the sorghum grain crop due to the residual nitrogen from the legume-based ley pastures (Cav-only and MP) was hypothesised to be a synergistic benefit in the cropping system. Fertiliser was applied to paddocks. Table 7 shows fertiliser inputs into the farming system; this is extracted from and discussed further in Bithell *et al.* (2013).

Table 6. *Soil samples from paddock No.1 (MP, Medium SR). Extracted from Bithell et al. (2013).*

Sample date	Crop stage	Depth (cm)
May 1995	Mixed pasture, year 1	0-15
February 1996	Mixed pasture, year 2	0-5, 5-15, 15-30, 30-60, 60-90, 90-120
March 1996	Mixed pasture, year 2	0-20
November 1996	Mixed pasture, year 2, pre-sowing sorghum	0-15, 15-30
May 1997	Post-harvest sorghum, pasture established?	0-5, 5-15, 15-30,
October 1997	Mixed pasture, year 1	0-10, 10-30
May 1998	Mixed pasture, year 1	0-15, 15-30
November 1998	Mixed pasture, year 2	0-15, 15-30
May 1999	Mixed pasture, year 2	0-15, 15-30
October 1999	Mixed pasture, year 2, pre-sowing sorghum	0-15, 15-30
May 2000	Post-harvest sorghum, pasture established	0-15, 15-30
December 2000	Mixed pasture, year 1	0-15, 15-30
May 2001	Mixed pasture, year 2	0-15, 15-30

Table 7. *Fertiliser inputs into the LFST treatments. Application values for NPKS fertilisers + te (trace elements, MOP=muriate of potash) with rates in kg/ha (adapted from Bithell et al. 2013).*

Season	Date	Pasture initiated	Applications	Grain initiated 1	Applications	Grain initiated 2	Applications
94-95	Nov 94	Leys	0.7.13.8 + te, 130 kg	Sorghum	0.7.13.8 + te, 130 kg	-	-
	Jan 95	Leys	0.11.20.6 + te, 83 kg	Sorghum	Urea, 95 kg	-	-
95-96	Nov 95	Leys	0.10.20.5 + te, 210 kg	Leys	0.10.20.5 + te, 200 kg	Sorghum	0.10.20.5 + te, 200 kg
	Dec 95 Jan 96					Sorghum	Urea, 50 kg Urea, 100 kg
96-97	Dec 96	Sorghum	0.11.20.6 + te, 180-233 kg 0.18.0.10, 32 kg, Urea, 0 to 240 kg*	Leys	0.11.20.6 + te, 196 kg	Sorghum	0.11.20.6 + te, 206 kg
97-98	Dec 97	Leys	0.16.0.20, 50 kg	Sorghum	0.11.20.6 + te, 200 kg	Leys	0.16.0.20, 50 kg
	Jan 98			Sorghum	Urea, 90 kg		
98-99	Dec 98	Leys	0.16.0.20, 50 kg	Leys	0.14.0.18, 50 kg	Sorghum	19.13.0.9, 200 kg
						Sorghum	Urea, 100 kg
99-00	Dec 99	Sorghum	MOP, 110 kg 19.13.0.9, 185 kg	Leys	0.14.0.18, 50 kg	Leys	0.14.0.18, 50 kg
	Jan 99	Sorghum	Urea, 100 kg				
00-01	Dec 00	Leys	0.14.0.18, 50 kg	Sorghum	MOP, 50 kg 19.13.0.9, 180 kg	Leys	0.14.0.18, 50 kg
	Jan 01			Sorghum	Urea, 90 kg		

* Indicates that split plot fertiliser treatments were used for that application.

Results and Discussion

Resource-intensive soil sampling and analysis was conducted over the duration of the LFST to assess the effect of ley pasture treatment on soil nutrition parameters. However, these data were not collated, and discussion of results could not be presented in this report.

Bithell *et al*. (2013) interpreted numerous historical soil test results, including data for the LFST, accounting for the absence of proper replication (methods varied with time and the fashion in which depth profiles were sampled) of rotation treatments. They examined changes in soil pH and oxidisable carbon between the Cav-only and MP treatments, categorising analyses of rotations as 'pasture-initiated' and 'grain crop-initiated'.

This is a different approach than presented in this report, where the rotation is based simply on comparison of two different ley pasture treatments, with the grain crop sown after two years of pasture. The conclusions by Bithell *et al*. (2013) remain comparable. However, the objective of their report was to determine whether the soil carbon and pH measurements were suitable for use as agricultural soil quality indicators for agricultural land in the NT. Soil nitrogen was not discussed, and there appears to be no data currently available for further analysis. Descriptive data was accessed through Technical Annual Reports, as described for the years below, although this was minimal. This was due in part, to the departure of Dr. Kandiah Thiagalingam, and no replacement soil scientist was appointed.

Erosion was a threat in the LFST paddocks due to the sandy soil type (Blain), a negligible slope, and crop/pasture treatments with associated removal of vegetative cover (Photo 13).

1994/95

Soil analysis at harvest (sown Jan 1995) showed a pH of 7.9, 7.3; organic carbon content of 0.58, 0.51 ; total N of 0.058 , 0.05 ; respectively for the Cav-only and MP treatments. Available P, K, S, Zn and Cu was low in both areas.

Total nitrogen content in the Cav-only leys averaged 145 kg N/ha whereas the MP leys averaged 90 kg N/ha. It was concluded that these were adequate soil nitrogen values to provide for pasture production in the leys (N.T. Government, 1995).

1995/96

Total nitrogen content in Cav-only leys averaged 127 kg N/ha compared to 90 kg N/ha for the MP leys.

Conclusion

A comparison of the contribution of the two ley pasture treatments, Cav-only and MP, to soil parameters was a major component to the evaluation of the LFST. Bithell *et al*. (2013) conducted a comprehensive analysis of changes in the soil pH and oxidisable carbon, suggesting that a near-complete (although variable) data set was available at that time. Other soil nutrition parameters were not evaluated. They found that Cavalcade had lower pH and lower oxidisable carbon concentrations compared to the MP, and that grazing had no significant effect on either of these parameters. However, differences were often rotation or sample date specific, which prohibited drawing general conclusion about ley pasture treatment effects.

It appears that analysis of nitrogen components, and comparison of the difference in contribution of the two ley pasture treatments to the subsequent sorghum grain crop, was not quantified.

Results for the two years described above, support the hypothesis that the legume ley would contribute more nitrogen than the MP ley to the cereal crop rotation. The contribution of the legume component to the grass component within the MP in the ley phase was not quantified. However, the production of good MP yields in the absence of nitrogen based synthetic fertilisers suggests that the legume component did contribute to grass biomass production.

Photo 13. *Erosion on Blain sandy soils is a threat if mulch cover is not adequate.*

Economic Evaluation and Model Development

Introduction

The rationale for ley farming is that there are expected production synergies, compared to a simple substitutional effect of one commodity for another (Kirby *et al.* 1996). Economic evaluation, including synergies between the enterprise gross margins, and sensitivity analysis comparing grain versus cattle prices, was a key component of the LFST. Gross Margin budgets were developed for grain crops and cattle production in the Douglas-Daly in the early 1990s (e.g. (Murti 1991; Murti 1993). However, it does not appear that an economic analysis was conducted based on the LFST to evaluate synergies between the grazing and cropping enterprises. It is acknowledged that this would not have been a simple undertaking.

Agricultural production models enable simulation of different scenarios to assess farming system performance. These models, such as APSIM (Agricultural Production Systems Simulator) are informed by biological and environmental modules such as soil characteristics, climatic variables and crop growth physiology. Carberry et al. (1996) examined and modelled sorghum and maize yields with Verano stylo as the legume rotation. The LFST intended to collect extensive baseline data to inform a farming system modelling scenario with Cavalcade and cattle grazing practices. This would contribute to assessment of long-term validity and applicability of a ley farming system in the Douglas-Daly region. It appears that no modelling was done incorporating the LFST trial data. Again, it is acknowledged that this would not have been a simple undertaking.

Economic evaluation and model development would be an essential criterion of any future assessment of an agriculture farming system.

Seasonal Conditions

An internal report presented monthly rainfall for the initial four years of the LFST (Fig. 22). The January 1998 flood event is evidenced by the approximate 800mm for that month.

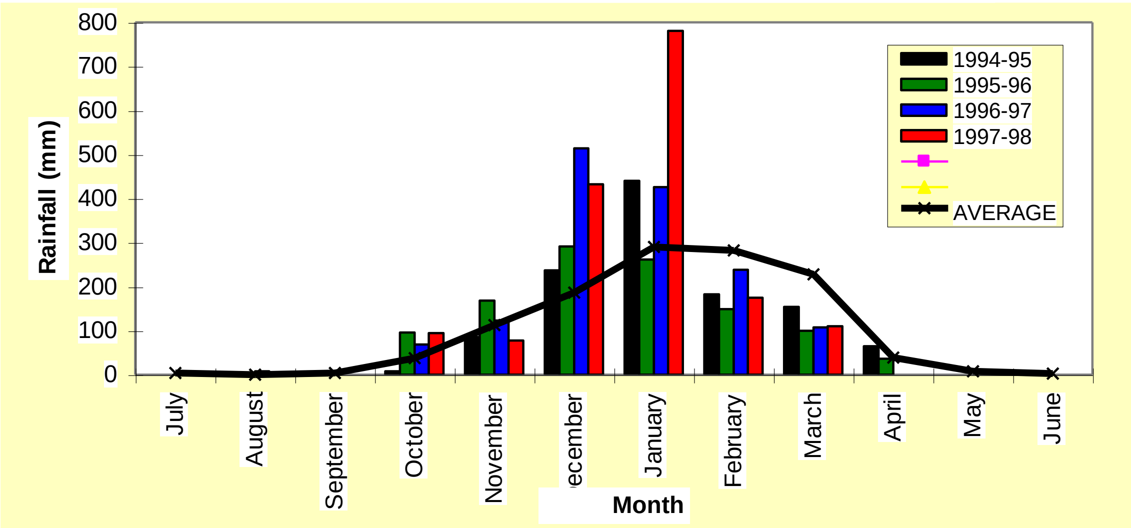


Figure 22. *Monthly distribution of rainfall at DDRF for the initial four years of the LFST, with the mean monthly rainfall superimposed. Source internal non-published report.*

Bithell *et al.* (2013) presented seasonal rainfall conditions at DDRF over the duration of the LFST (Table 8). This shows the predominance of rainfall which occurred in the months of December to April.

Table 8. *Rainfall recorded at DDRF for the LFST for the long-term average wettest months (1 December to 30 April), annual seasonal rainfall (1 July to 30 June) and the December to April rainfall as percentage of annual seasonal rain, including mean, standard deviation, coefficients of variation (CV) and long term average rainfall (sourced from Bithell et al 2013).*

	Dec.-Apr.	June-July	% wet of annual
Average for 1968-2011	1067.4	1182.7	90.3
1994-1995	782.9	849.6	92.1
1995-1996	965.1	1096.7	88.0
1996-1997	1064.2	1269.2	83.8
1997-1998	1595.6	1695.8	94.1
1998-1999	1472.3	1590.6	92.6
1999-2000	1289.5	1449.4	89.0
2000-2001	1080.4	1192.8	90.6
Mean	1178.6	1306.3	90.0
Std. dev.	287.9	294.3	3.4
CV	0.24	0.23	0.04

Overall Discussion and Conclusion

The LFST conducted at DDRF from 1994 to 2002 evaluated the synergies between cropping and beef production on two different ley pastures in a sorghum grain crop / pasture rotation. Only one study in the Australian semi-arid tropics previously had evaluated an experimental ley pasture system and animal production data (Winter *et al.* 1996). The DDRF LFST was the first experiment in the NT to compare legume only and mixed legume-grass ley pastures in a crop rotation. It was a significant long-term research project and the first of its type when introduced in 1994 to attempt to integrate a multi-disciplinary approach to agriculture in the NT. It remains one of the best examples of a multi-disciplinary project conducted in the NT to date but results from the LFST were not collated. This Technical Report rectifies this. The report outlines the method, results and general conclusions regarding the components of the LFST, namely pasture production and associated weed management and mulch management dynamics, cattle production and crop production.

The DDRF LFST compared the dynamics of a legume only (Cavalcade) and a mixed pasture (MP) legume-grass (Cavalcade/Sabi grass) treatment when grazed at three stocking rates (SR) over the Dry season. These pastures were grazed for the first and second years of establishment, then sown to sorghum no-till. Generally, the MP treatment produced greater biomass than the Cav-only treatment prior to introduction of cattle grazing over the Dry season. This was not unexpected, due to the benefits of synergies in growth habits and physiology between a grass-legume pasture mix.

There were a range of factors which influenced the proportion of grass to legume in the MP, but generally the proportion of Cavalcade in the MP declined in the 2nd-year pasture following the 1st-year pasture. This was mostly attributed to the competitive advantage of an established perennial grass, and selective grazing of the legume component within the MP over the Dry season. Maintaining the legume-grass balance is acknowledged as a significant constraint in a mixed grazed pasture. The relative absence of legume by the end of the 2nd year pasture also raises the question on whether the nitrogen has been depleted prior to the sowing of the cereal crop, effectively reducing the benefit of the nitrogen contribution of a legume-based ley pasture. This data was collected over the duration of the LFST to answer this question, but data was not available for this report.

Seasonal conditions affecting residue breakdown in the Dry season and early Wet season may also have a large effect in the Douglas-Daly environment. For example, 53% of the N in 1st year Cavalcade ley pasture residues was identified as being mineralised between May and November in trials at DDRF, with this nitrate considered to have been potentially leached by early Wet season rains (Thiagalingam *et al.* 1995). For the 2nd year ley, this figure for N mineralisation was lower at approximately 20%. This has implications for ley pasture nitrogen contribution to the subsequent cereal grain crop.

Another key constraint in a mixed pasture is weed control, with no broadacre herbicide options available. Broadleaf and grass weeds were observed to establish in both the MP and Cav-only pasture treatments. Effectiveness of imazethapyr in Cav-only was variable, influenced by season and timing of application, especially in the 2nd-year pasture. In some seasons, broadleaf weeds, mainly Hyptis and sicklepod, dominated both pasture treatments by the second season. A broadleaf selective herbicide was used in the MP, causing collateral mortality of the Cavalcade, and in the Cav-only, this was treated with a knockdown herbicide, and re-sown, effectively changing the dynamics to a 1st-year sown pasture treatment.

Weeds remain a significant constraint to agricultural production in the NT, both in pastures, and in cropping, including the emerging cotton production industry, even with Roundup Ready® technology.

The Stocking Rate treatments were not imposed over the Wet season, although some set stocking grazing occurred on the MP paddocks, and some crash grazing for mulch management occurred in paddocks intended for sowing sorghum. This was evidenced by the lack of SR effect at the time of the May pasture measurements, but a SR effect evident at the (limited) November data after the Dry season grazing period. This effect was more pronounced after the 2nd-year grazing compared to the initial establishment year. This suggests that variability in pasture establishment and biomass in the 1st-year confounds any grazing effects, but this inconsistency stabilises as the pasture establishes over the second Wet season. This has implications for general grazing management, where grazing pressures in a pasture establishment season can have carry-over effects on the longevity of a sustainable pasture.

Mulch management prior to sowing sorghum no-till was a challenge. The low biomass of the Cav-only treatments was one of the main determinants for timing the removal of cattle at the end of the Dry season grazing period. Re-establishment of ground cover was then dependent on new growth post-grazing, either of Cavalcade from hard seed, or usually low bulk annual summer grasses (e.g. *Digitaria* and *Brachiaria* species). This was confounded by seasonal differences, especially early Wet season rainfall distribution.

Conversely, the MP treatments needed to be crash grazed to reduce biomass to a desirable 2 – 3t/ha. Even with heavy grazing to reduce biomass, sowing no-till through Sabi grass tussocks was observed to result in uneven planting seed depth and more variable establishment compared to sorghum following Cav-only. This confounded the conclusions comparing nitrogen contribution of the ley pasture treatments to subsequent sorghum grain yield. The LFST model facilitates mulch management through use of cattle grazing, although this may not always be feasible in other farming systems. The impact of grazing on subsequent soil properties such as soil compaction was not quantified.

Mulch management in no-till farming systems remains a key challenge, especially with variability in Wet season duration and rainfall distribution, confounded if grazing is introduced into the system.

The seasonal variability also produced differences in time of cattle turnoff depending on break in season and feed remaining in the treatment paddocks, so actual number of grazing days over the Dry season varied. Grazing for mulch management, grazing for liveweight gains, and keeping cattle on MP treatment paddocks over the Wet season was a balance of practicality and addressing the research questions. Cattle weight gains were recorded monthly throughout the LFST, but these detailed data could not be found for this report (were subsequently located in the DDRF Archives room). Results and discussions are based on total liveweight gains over the entire Dry season treatment period, acknowledging that maintaining liveweight in the Dry season / Wet season transition period is critical to overall improved cattle productivity.

Generally, the sorghum following the Cav-only pastures had higher average grain and stover yields across SRs compared to the MP across seasons. This was theorised due to a combination of increased nitrogen contribution from the Cavalcade, less AMG from use of selective herbicides in Cavalcade, and generally better sorghum establishment due to easier planting into the Cavalcade mulch. The better crop populations also allowed for some compensatory growth against one of the key constraints for achieving high sorghum grain yields – bird damage. Bird damage remains a key constraint for agricultural production in the Douglas-Daly area.

The Sabi and Cavalcade generally regenerated well following the sorghum crop, which negated the cost of sowing for a 1st-year pasture. Cavalcade was noted to provide intercrop competition as it emerged within the sorghum crop and caused difficulties with grain harvest due to its twining growth habit. However, sorghum stubble with establishing Cavalcade provided the highest cattle weight gains over the Dry season. A cost-benefit analysis with a range of cattle liveweight gains and grain sorghum yields could provide some insight into sustainable, flexible and resilient mixed farming systems. Acknowledging that getting grain actually into a header in the Top End can be a challenge due to bird damage, an option could be using a forage sorghum in a grazing / crop rotation. This could also negate the issues associated with harvesting using a twining legume such as Cavalcade in the pasture rotation.

In acknowledgment of the constraints identified over the 1994-2002 duration of the LFST, a review of the project was conducted in 2002 (refer Appendix 3). Ultimately, the LFST, or any iteration of it, was discontinued after 2002. This was likely due to budget and resource constraints given that it was labour and resource intensive research project. However, some of the conclusions and recommendations are still relevant.

Although cattle weight gains were achieved on the Cav-only treatment in the LFST, they 'crashed' earlier in the season with onset of rains causing deterioration in legume quality and availability. It was concluded that a pure Cavalcade pasture was relatively inefficient as a set stocked grazed pasture over the Dry season. Currently, Cavalcade fills the niche of producing a high protein quality hay. Broadleaf weed invasion remains one of the major constraints. Extensive damage by magpie geese to Cavalcade crops in the Douglas-Daly has been reported in recent seasons. A suitable crop rotation such as cotton, which could utilise accumulated nitrogen, could control broadleaf weeds (which could subsequently include Cavalcade) through application of glyphosate and Roundup Ready® technology, and with relatively low susceptibility to bird damage could be a feasible option. This would need to be assessed further.

The MP provided a combination of bulk and improved quality through higher protein from legumes in the grazing mix compared to 'traditional' grass only pastures, for improved cattle production over the Dry season treatment period. The MP also provided an option for continued grazing over the Wet season. This enabled better pasture utilisation, for example, through a reduction in shading of standing biomass in the understorey and also minimised the traditional decline in cattle liveweight in the Dry season/ Wet season transition period. However, lack of broadacre weed control options, and maintaining the legume-grass balance were key constraints in the MP paddocks, consistent with a range of previous studies.

A recent demonstration of novel technology to direct drill legumes into existing pastures provides an opportunity to maintain a legume-grass pasture mix. The term 'no-kill, no-till' direct drilling legumes into grass pastures, without using a knockdown herbicide to kill vegetation prior to sowing, maximises utilisation of the grass pasture, with subsequent improvement in pasture quality through addition of a legume such as butterfly pea (*Clitoria ternatea*) (O'Gara & Eastick, 2024).

This may provide a solution for two of the main issues in mixed pastures – broadleaf weed invasion and lack of suitable herbicides, and ultimate grass dominance. A broadleaf herbicide (e.g. 2,4-D amicide) was applied to eliminate broadleaf weeds which had started to dominate the MP in some years in the LFST, resulting in collateral mortality of the Cavalcade. This weed control practice could now occur in the knowledge that 'no-till, no-kill' direct drilling of legumes back into the grass pasture was an option. This may allow inclusion of a sustainable mixed pasture rotation into a farming system, with the associated benefits of legumes to cattle productivity and soil health.

A major component of future agricultural systems is accountability for greenhouse gas emissions. This was not considered a component of the DDRF LFST. However, increased cattle productivity, such as could be provided by incorporation of legumes into grazing systems, and higher quality feed (e.g. grain or forages) to reduce number of days to achieve target cattle weights, provides a significant avenue for overall reduction in agricultural GHG emissions. A mixed pasture ley farming system could potentially provide such an outcome.

General trends and conclusions are discussed here. More detailed statistical analyses would increase understanding in the complex interactions which were observed throughout the duration of the project. For example, inconsistencies in the SR effect on ley pasture treatment type may be better understood if correlation between seasonal pasture biomass and cattle liveweight gain was considered. There may be opportunity in the future for more detailed analysis to occur to support development of northern farming systems. This more detailed analysis should also include socio-economic evaluation and modelling of different crop-pasture rotations across seasonal variability and soil types.

Overall, the multi-disciplinary DDRF LFST was a complex and ambitious project. It evaluated a number of components and their interactions, which until now, had not been collated and made publicly available. Although significant treatment effects and their interactions were not statistically evaluated, statements of pasture biomass, cattle weight gains and sorghum yields achieved over the multiple seasons are presented here. General conclusions are discussed, based on trends in the data for pasture and weed dynamics, cattle production and crop production, and observations in the field over the duration of the project.

The collation of available data from the LFST into this Technical Report aims to increase the awareness of the lessons learnt and the outcomes from the LFST. The results and learnings from the LFST may complement current and future projects/platforms. This includes the 'Cotton Grains Cattle Program' supported by the Cooperative Research Centre for Developing Northern Australia (CRCNA), with a 'Crops for Cattle' Project (Crops for cattle - FutureBeef) and 'Addressing the Fundamentals of Cropping Systems in the NT (Cotton Grains Cattle program: Addressing the fundamentals of cropping-systems in the Northern Territory - Cooperative Research Centre for Developing Northern Australia). The LFST Technical Report aims to build on historical knowledge to help inform current and future farming system strategies in the Top End to enhance agricultural practices of stakeholders.

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The authors acknowledge the vision of the initial project supervisors, Tony Hooper (dec.). Colin McCool (dec.), and Kandiah Thiagalingam, and the leadership of Barry Lemcke and the technical expertise of Nick Hartley over the duration of the LSFT, and contributions from Sean Bithell, Narelle Hill and numerous staff at Douglas Daly Research Farm.

Technical Information

Herbicides referenced

Common name	Active ingredient
2,4-D Amicide (various trade names)	Various, e.g. 2,4-D present as dimethylamine salt (720 g/L)
Atrazine (various trade names)	Various, e.g. Atrazine WG (900g/kg)
Basagran®	Bentazone (480 g/L)
Dual® (Dual Gold®)	S-Metolachlor (960 g/L)
Fusilade	Fluazifop (128 g/L)
Sertin®	Sethoxydim (186 g/L)
Spinnaker®	Imazethapyr (700 g/kg)
Verdict®	Haloxyfop (520 g/L)

Plant names

Common name	Scientific name
Annual mission grass (AMG)	*Cenchrus pedicellatus (formerly Pennisteum pedicellatum)*
Butterfly pea (Blue pea)	*Clitoria ternatea*
Cavalcade	*Centrosema pascuorum cv.* Cavalcade
Hyptis	*Hyptis suaveolens*
Phasey bean	*Macroptilium purpureum*
Pigweed (Black)	*Trianthema portulacastrum*
Pigweed (Red)	*Portulaca oleracea*
Rattlepod	*Crotalaria spp.*
Sicklepod	*Senna obtusifolia*
Sabi grass	*Urochloa mosambicensis cv* Nixon
Sesbania	*Sesbania spp.*
Spiny Sida	*Sida acuta*
Stylo	*Stylosanthes spp.*
Summer grass	*Digitaria spp. and Brachiaria spp.*

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Appendix 1. Herbicide screening in Cavalcade 2003-04

HERBICIDE SCREENING IN CAVALCADE 2003-04
Internal Technical Report

ROWENA EASTICK

Collated Jan 2007.

BACKGROUND

Spinnaker had been previously identified as the most effective herbicide for use in cavalcade, but did not control senna, a major problem in cavalcade crops. There was continued demand for herbicides to provide additional scope for broadleaf weed control. Raptor, with similar chemistry to Spinnaker, had shown promise in previous trials, so was re-assessed. Two relatively new herbicides, Sniper and Balance, were registered for use on specific legume crops, so were considered to have potential for use in cavalcade. If suitable, these would increase cavalcade herbicide options, with the added benefit as Group F herbicides they could be rotated with Spinnaker (Group B) to avoid development of herbicide resistance.

METHOD

Experimental Design and Location

A non-replicated split plot trial area on the Blain soil irrigation area at DDRF.
Main plot was tillage – conventional or no-till sown cavalcade.
Split plot was herbicide – 6 treatments applied at either post-plant pre-emergence, or post-emergence when the cavalcade was beyond the 3-leaf stage.
Plot size was 15m x 6m.

Trt	Trade Name	Active (g/kg)	When applied	Rate (g of product)
1	Raptor	imazamox (700g)	Pre	50g
2	Raptor	imazamox (700g)	Post	50g (+0.2%BS1000)
3	Sniper	picolinafen (750g)	Pre	40g
4	Sniper	picolinafen (750g)	Post	40g
5	Balance	isoxaflutole (750g)	Pre	100g
6	Control	No herbicide	-	-

Husbandry

Roundup CT (450g/L + 0.25%LI700) was applied at 4L/ha on 21st Jan 2003. Weeds present at the site included: *Brachiaria pubigera*, *Digitaria* spp., button grass (big and small), caltrop, *Pterocaulon* spp, tarvine, *Senna obtusifolia*, *Sida acuta*, *Eragrostis* spp, buffalo clover, pigweeds (red and black), tridax daisy, *Vernonia* spp and *Ipomea* spp.
Cavalcade was sown on the 5th February. Pre-emergent herbicide treatments were applied immediately after sowing using a 3m Agmurf plot sprayer.
Post-emergent treatments were applied on the 21st March. Cavalcade was up to 20cm in height and 5-7 true leaf. Weeds ranged from 2-10 leaf, with some pigweeds up to 20cm diameter.

Measurements

Visual ratings and photos were taken on the 19th February (14DAS), 21st March (pre-emergent treatments only; 6 weeks after pre-application, and corresponding to timing of post-application) and 24th April (10weeks after pre-emergent application; 4 weeks after post- application).

RESULTS

Herbicide treatment	1st rating 19th February		2nd rating 21st March		3rd rating 24th April	
	Cavalcade	Weed	Cavalcade	Weed	Cavalcade	Weed
Raptor pre	Cotyledon and 1 true-leaf stage	Very few emerged	Robust 5-leaf+ stage	Trianthema (10cm diam), Pterocaulon (up to 10cm ht) & Vernonia unaffected	>40cm diam. Robust	Vernonia>50cm and flowering. Caltrop killed or suppressed
Raptor post	-	-			>40cm diam. Robust	Vernonia shriveled and flowering aborted. Pterocaulon, tarvine & caltrop(20cm) present at time of spraying – some suppression. Button & summer grass dead
Sniper pre	Cotyledon and 1 true-leaf stage	Mainly pigweeds at 1-2 leaf	Slightly stunted, 5-leaf stage	Trianthema stunted and yellow. Tarvine & ipomea unaffected	>40cm diam. Robust	Vernonia>50cm and flowering, tarvine>50cm
Sniper post	-	-			>30cm diam. Slightly stunted	Vernonia>50cm and flowering, tarvine>50cm, caltrop>30cm
Balance pre	Slow and decreased emergence	None emerged	Stunted, some yellowing, reduced biomass	No effect on senna. Vernonia (rosette @4cm diam), tarvine(up to 10cm diam) dominant. No pigweed yet emerged.	>30cm diam. Slightly stunted	>50cm tarvine, >30cm caltrop & vernonia
Control	Cotyledon and 1 true-leaf stage	Mainly pigweeds at 1-2 leaf	Robust 5-leaf+ stage	Caltrop (up to 20cm), Pterocaulon (10cm), Vernonia, Trianthema		>50cm tarvine, >30cm caltrop & vernonia flowering

Figure 1. No-till strip 21st March (6 weeks after sowing and pre-emergent herbicide application). Balance pre-emergent treatment in foreground.

Figure 2. Conventional-till strip 21st March (6 weeks after sowing and pre-emergent herbicide application). Balance pre-emergent treatment in foreground.

DISCUSSION AND CONCLUSION

Herbicide, application timing, tillage and soil interaction, the weed spectrum, and a dry wet season all influenced cavalcade and weed biomass.

Raptor produced the best results overall, with no phytotoxicity on the cavalcade, and was effective on a range of weeds, such as caltrop, pterocaulon and grasses (Digitaria and button grasses) and suppression of vernonia. The post-emergent application resulted in greater cavalcade biomass and less weed biomass than the pre-emergent Raptor application. Raptor produced results consistent with those from Spinnaker in other experiments, but has less residual life. Residual activity of herbicides over the wet season is desirable for longer-term weed control, so Spinnaker would probably be the better option over Raptor (and similar cost).

Sniper acts primarily by foliage absorption, and is mainly registered for post-emergent use. However, it has some soil activity, so we decided to try it pre-emergent. There was minimal weed control when applied at this stage. Sniper applied post-emergent was slightly more effective, but overall, provided little control of the main weeds at this site – pigweeds early in the season, and subsequently vernonia and caltrop. However, this herbicide produced minimal phytotoxic effect on cavalcade, so should be re-assessed at a different site with a different weed spectrum. It was difficult to assess effect on senna, as there were only isolated plants at the site, and absence of senna seedlings did not necessarily mean that this was due to the effectiveness of the herbicide.

Balance produced a reduction in early cavalcade growth, and did not effectively control the major weeds at this site. Senna was observed in the conventional till Balance plot, indicating this herbicide would not effectively control this weed. Although cavalcade recovered to a great extent by the end of the season, biomass was less than that observed for all other treatments, likely due to a combination of herbicide damage and weed competition.

Herbicide effects were consistent between tillage treatments, although the Balance pre-emergent appeared to produce greater crop damage in the conventional than the no-till on this sandy soil (Figures 1 & 2). Assessment of these herbicides on soil types other than sandy Blain would be worthwhile.

The 2003-04 wet season had a late start and below average rainfall, so cavalcade (and weed) growth was less than expected, and there was little recovery period for compensatory growth if there was early herbicide damage.

This trial was non-replicated and presented qualitative results only. The weed spectrum also was relatively specific for this site. A range of herbicides has been assessed over a number of years, most of which have substantially damaged cavalcade. Although Sniper did not result in a weed-free plot, by merit of the tolerance of cavalcade to this herbicide, it would be worthwhile to conduct further assessment of this herbicide. This would necessarily encompass a different soil type, a different season, and a different weed spectrum. Further work on these chemicals was not previously conducted, as results were not as effective as those for Spinnaker. However, the demand for an alternative mode of action herbicide suitable for use in cavalcade, still remains, and a replicated experiment at least comparing Spinnaker and Sniper, should be conducted.

Appendix 2. Pre-Wet season herbicide management in Cavalcade 2003-04

PRE-WET SEASON HERBICIDE MANAGEMENT IN CAVALCADE
Internal Technical Report

Rowena Eastick, Nick Hartley, DDRF staff

Collated Jan 2007

A project was initiated in the 2003-04 wet season to assess efficacy of Spinnaker and Flame in self-sown cavalcade prior to the first rain of the wet season. This document presents the background, method, results and conclusions from this work.

Project Officers: **R. Eastick, N. Hartley, P. Shotton and M. Hearnden**

Location: Bay 11 and Farming Systems Paddock 19, DDRF

Objective:

To determine the suitability of pre-wet application of Spinnaker® or Flame® for weed management in self-sown Cavalcade.

Background:

Cavalcade is predominantly grown as an annual crop, where production is based on seed sown each season from late November to early January. Peak flowering and seed set generally occur about mid- April, with seed maturing three to four weeks later. The crop may be cut for hay in late May to June, or can be utilised for high quality stand-over feed for grazing in the dry season. Consequently, often abundant seed remains on the soil surface, which may provide a greater opportunity for germination than the 6-10 kg/ha of seed recommended for sowing. This provides for a self-sown second season Cavalcade. This has the advantages of: no need for seed purchase and sowing costs, a vigorous early establishment of a high density Cavalcade population which may provide a competitive advantage over weeds, and access to available soil moisture in a poor wet season.

However, the initial rain that stimulates Cavalcade germination also stimulates germination of weed seeds, with vigorous early growth which may out-compete emerging Cavalcade seedlings, and which may get too large for effective control by Spinnaker®. Application of a knockdown herbicide, e.g. glyphosate, is another management option, with reliance on a second germination of Cavalcade seed, whose seedlings tend to be less vigorous.

We investigated a strategy to apply a pre-emergence herbicide towards the end of the dry season relying on residual herbicide activity for effective weed control at the start of the wet season. Spinnaker® is currently registered for post-plant pre-emergence application for a range of weed species in Cavalcade, generally applied immediately after sowing. Flame® is registered for the pre-emergence control of certain grass and broadleaf weeds in fallow situations and in peanuts and has shown some promise in other Cavalcade plot trials. Therefore, it may be a suitable herbicide for pre- wet season application. Both these imidazolinone herbicides have considerable soil residual activity, where Flame® is considered to display greater persistence in soils (three to six months) than Spinnaker® (two to three months), although this will be influenced by other factors such as weather and soil characteristics (www.oznet.ksu.edu/library/crps12/c-707.pdf).

It will be necessary to determine the period for which residual activity of these herbicides is maintained on the soil surface, to allow latitude in application timing due to difficulty in predicting the onset of the wet season.

This study aims to evaluate efficacy of Spinnaker® and Flame® on weeds when applied at different times prior to the onset of the wet season.

Method:

Experimental design and location

This was a non-replicated experiment. Herbicides were applied in strips in sequence over time in Paddock 19 of the Systems Trial - a Blain sandy soil, and Bay 11 - a Tippera clay-loam at DDRF. There was considerable (>2 t/ha) dried Cavalcade mulch on the soil surface in Bay 11.

Treatments

Herbicides

Spinnaker 700WDG® (700 g/kg imazethapyr) at two rates:
L: @ 140 g/ha (maximum recommended rate; 98 g/ha a.i.)
H: @ 280 g/ha (double maximum recommended rate; 196 g/ha a.i.)
Flame® (240 g/L imazapic) at two rates:
L: @ 400 mL/ha (maximum recommended rate, 96 g/ha a.i.)
H: @ 800 mL/ha (double maximum recommended rate; 192 g/ha a.i.)

The double rate was applied by a second run over the strip rather than mixing up a different tank, effectively also applying double the amount of carrier to the area. Herbicides were applied by a quadbike-mounted 4-m boom.

Time of application

Initial application was on 12 September, of both low and high rates. Subsequent applications of the low rates only were applied every two weeks. Both low and high rates were applied every alternate time (4 weekly) until the final application on 7 November, after which germinating rainfall was considered to have fallen; 5 November (11 mm) and 14 November (18 mm).

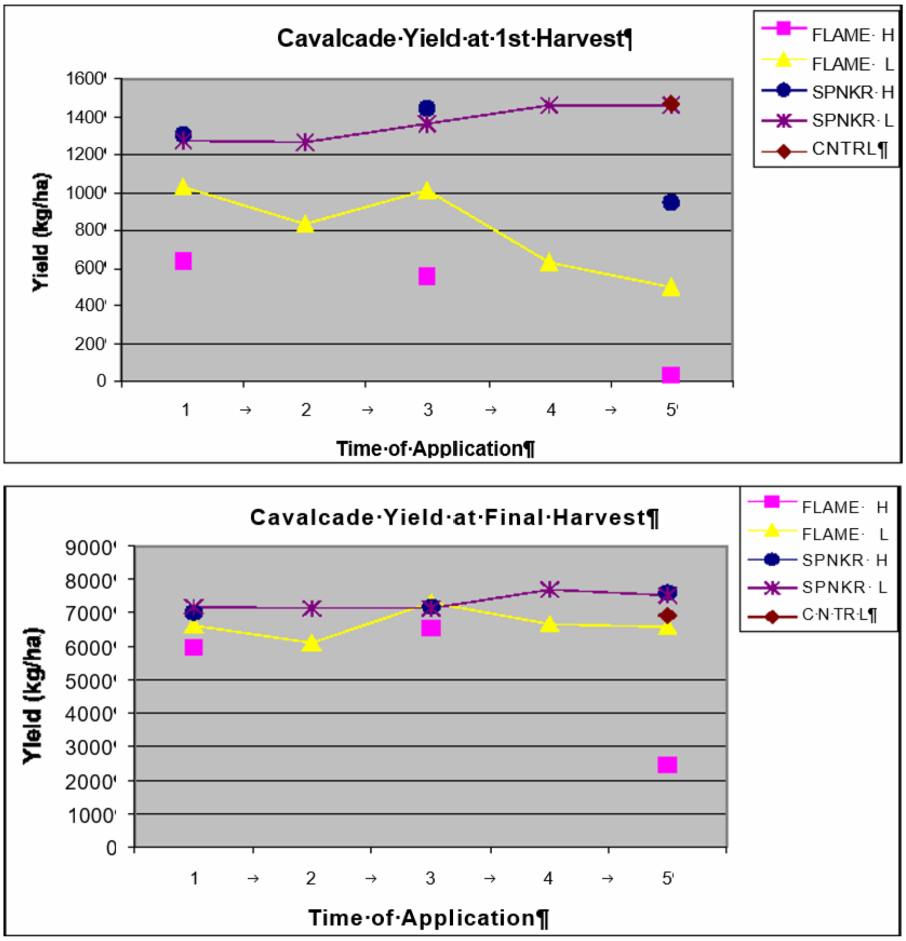
Measurements

Biomass samples of four quadrats (0.5 m x 0.5 m) per plot, plus a control plot where no herbicides had been applied, were taken on 20 December 2003 and 5 February 2004 to determine herbicide phytotoxicity on Cavalcade and weeds.

Results:

Trends observed at the initial harvest were that the most recent application (T5) of Flame at both rates, and Spinnaker at the high rate caused a decline in Cavalcade yield compared with the Spinnaker low rate and control plots (Figure 1a). However, by the time of final harvest, this decline at T5 was only observed for the Flame high plot (Figure 1 b).

Excellent weed control, particularly of grass weeds, was observed in all treatments.



Figures 1a and 1b. Cavalcade yields (kg/ha) for initial and final harvests

Discussion and Conclusion:

Results indicate that it is possible to apply either Spinnaker, with no apparent rate effect, or Flame at the low rate, prior to the anticipated start of the wet season, to control early germinating weeds. It appears that Spinnaker at the recommended rate of 140 g/ha could be applied as early in the season as 12 September, corresponding in this instance, to eight weeks before initial rains. It is intended in the 2004-05 season to adopt a best-bet management option of applying Spinnaker® in the last week of October to assess its effects on a larger scale in Bay 11.

Although results for Paddock 19 are not presented, trends were similar, although residual activity of both herbicides appeared to be longer for the Bay 11 site than for the Paddock 19 site, consistent with other findings of lower persistence of imidazolinone herbicides in more sandy soil.

Appendix 3. Farming Systems Project Review 2002

Internal Project Review

1. AGRICULTURE DEVELOPMENT MISSION STATEMENT

To develop sustainable and profitable farming systems for agricultural production in the Top End.

PROJECT OBJECTIVE

To compare the economic and production sustainability between four paddock treatments and to develop weed management options within each treatment.

BACKGROUND

A Ley Farming Systems Project commenced in 1995 to examine an integrated farming system based on a grain crop/pasture rotation and associated cattle production. This incorporated a two-year pasture production phase of either cavalcade only or mixed Sabi/cavalcade, grown in rotation with a one-year grain sorghum crop, constituting a three-year rotation. Cattle weaner weight gain on the pasture and sorghum stubble phases was evaluated at three stocking rates.

Two entire rotations will be completed at the end of the 2002 dry season. This provides an opportune time to review the Farming Systems Project. There are two broad options for the project; Closure; or continuation of the project with modified paddock treatments. Data for the project to date is currently being collated, but it is evident that the design and specific paddock treatments needs modification both for relevance to production systems in the Top End and also for robustness of statistical analyses.

There is uncertainty concerning the optimum activity(ies) for a medium to long term management strategy for a given paddock. Dominant activities currently in evidence in the Douglas Daly region include cavalcade hay production and grass only pastures e.g. Sabi, Buffel, Jarra for cattle production. Mixed pastures for cattle production provide optimum annual weight gains but management of species mix may be difficult. The long-term economic and agronomic sustainability of these different production strategies is not quantified, encompassing yields, cattle production, weed control, and soil health.

Weed invasion is considered a major constraint to agricultural production. This reduction in productivity, and associated loss of returns, plus the advent of the Weeds Act and legislative requirements means that producers need to be provided with farming systems which have sound weed management principles. This includes consideration of rotation of herbicide groups to prevent risk of development of chemical resistance. Weed population thresholds to determine the sustainability of implementation of weed control over time is a supplementary component of an integrated weed management plan, and future work may need to reflect this.

Large-scale replicated paddock treatment comparisons are often logistically difficult due to establishment of infrastructure and resources. The existing infrastructure of 20 paddocks, of either 4 or 6 ha allows for a comparison of paddock treatments.

The assumption is made that the paddock exists in a ‘weedy state’ (broadleaf and grass) as this would provide the incentive to initiate a weed management strategy. What is the best medium to long-term option to renovate this paddock?

The aim is to develop a best-bet farming system based on a mixed enterprise of cattle, pasture and hay production as consistent with the current demand for agricultural production in the Douglas Daly region. This would be assessed over a minimum 4-year rotation to enable recommendation of best-bet options.

METHODOLOGY

Experimental Design:

Randomised complete block, 3 blocks

4 treatments

1) Cavalcade only
2) Grass only
3) Mixed pasture (Sabi/cavalcade)
4) Rotation strategy; Forage sorghum (2 years), Cavalcade (2 years), Sow mixed pasture (Cavalcade/Jarra/Sabi)

Design layout is presented in Table 1.

Forage sorghum is following; Sacrifice sorghum, Cavalcade 2nd year and Sorghum following cavalcade.

Cavalcade only is following: Mixed 2nd year, Cavalcade 2nd year and Sorghum after mixed.

Grass only is following: Mixed 2nd year, Mixed 1st year, Sorghum after mixed

Mixed pasture is following: Mixed 2nd year, Cavalcade 2 year, Sorghum after mixed

Suggested modifications and rationale for changes are provided in Table 2.

Measurements

1. Pre-season

a) Soil fertility status, especially considering different paddock histories as a starting point for the randomised paddock treatments.

b) Weed species present (again considering the different paddock histories)

2. Within season

a) Botanal at beginning and end of wet season – need to document weed populations, particularly differences in resultant species frequencies as a consequence of varying prior paddock treatments (existing Ley Farming Systems Trial).

b) Cattle weight gains monthly

c) Soil health (Organic Matter, Bulk Density)

Paddocks 8-14 are left to be utilised as a sorghum grain crop, for supplementary cattle weight gain experiments if required. Issues with these paddocks include a relatively steep slope at far end of the paddocks, plus low-lying areas with a tendency to pool water over the wet season.

Cavalcade for greater than two years is likley to be unsustainable due to high weed burden. The option is available to grow forage sorghum when deemed necessary (in the 3rd or 4th year).

Can reduce forage sorghum phase to one year only instead of two years. May be dependent on weed spectrum.

Mixed pasture may not be sustainable for greater than three years. Option is available to re-introduce a legume component (how?)

Table 1.

PDCK NO /YR	3. BLOCK 1				4. BLOCK 2				5. BLOCK 3			
	56	1	2	3	4	5	6	7	15	16	17	18
2002	Sacrifice sorghum	Mixed 2nd Yr	Mixed 2nd Yr	Mixed 2nd Yr	Cav. 2nd Yr	Cav. 2nd Yr	Cav. 2nd Yr	Mixed 1st Yr	Sorghum after Cav.	Sorghum after Mixed	Sorghum after Mixed	Sorghum after Mixed
2002-3	4 Rotation Forage sorghum	1 Cav. Hay	3 Mixed pasture	2 Grass only pasture	3 Mixed pasture	4 Rotation Forage sorghum	1 Cav. Hay	2 Grass only pasture	4 Rotation Forage sorghum	2 Grass only pasture	3 Mixed pasture	1 Cav. Hay
2003-4	4 Rotation Forage sorghum	1 Cav. Hay	3 Mixed pasture	2 Grass only pasture	3 Mixed pasture	4 Rotation Forage sorghum	1 Cav. Hay	2 Grass only pasture	4 Rotation Forage sorghum	2 Grass only pasture	3 Mixed pasture	1 Cav. Hay
2004-5	4 Rotation Cav. Hay	1 Cav. Hay	3 Mixed pasture	2 Grass only pasture	3 Mixed pasture	4 Rotation Cav. Hay	1 Cav. Hay	2 Grass only pasture	4 Rotation Cav. Hay	2 Grass only pasture	3 Mixed pasture	1 Cav. Hay
2005-6	4 Rotation Cav. Hay	1 Cav. Hay	3 Mixed pasture	2 Grass only pasture	3 Mixed pasture	4 Rotation Cav. Hay	1 Cav. Hay	2 Grass only pasture	4 Rotation Cav. Hay	2 Grass only pasture	3 Mixed pasture	1 Cav. Hay
2006-7+	4 Rotation Mixed pasture	1 Cav. Hay	3 Mixed pasture	2 Grass only pasture	3 Mixed pasture	4 Rotation Mixed pasture	1 Cav. Hay	2 Grass only pasture	4 Rotation Mixed pasture	2 Grass only pasture	3 Mixed pasture	1 Cav. Hay

Table 2.

PREVIOUS COMPONENT	MODIFICATION	RATIONALE
Sorghum grain crop 1-year production Cattle graze stubble and self-regenerating pasture for the two years following	Not grown as part of the system Is still maintained as a source of high quality feed for supplementary cattle weight gain trials; e.g. heifer joining	Little interest in sorghum grain crop in the region Difficulties in establishment, bird and weed control, especially on this soil type.
Cavalcade pasture Self-regenerating over two years Grazed	Cavalcade grown for hay production	Cavalcade as a grazed pasture species crash after the first rains with associated reduction in cattle weight gains. Costs in maintaining a pure cavalcade stand due to invasion of annual grasses and difficulties in control of broadleaf weeds. This is exacerbated when grazed (reducing competitiveness of desirable species) and inefficient use of legume for cattle production.
Mixed pasture Self-regenerating over two years	Maintain for longer than two years	Mixed pasture establishing at adequate species mix and biomass, then is 'blown out' in preparation for a sorghum grain crop is not considered economically sound. Agronomically, need to consider changes in species mix, especially by 2nd rotation (grass dominance inevitable).
Cattle grazing Three Stocking Rate treatments	Stocking rate consistent within paddock treatment (can be different between treatments).	Reduce grazing intensity effects to more confidently predict paddock treatment effects.

ADDITIONAL COMPONENT	RATIONALE
Forage sorghum	High demand for hay for live cattle export feed-on products Competitive crop for weed control Utilise residual nutrition
Grass only pasture	Provides the greatest option for weed management within a paddock treatment. Nitrogen fertiliser an additional cost.
Rotation strategy	An integrated farming system allows flexibility in the use of resources such as machinery and labour, spreads risk for commodity price changes, and provides options of weed management.

<u>More Information</u>

See Weed Control using Herbicide Roller and Slashing Methods 1999-2000, by Peter Shotton.

Much work was done in December 1999 – January 2000 to investigate the main factors contributing to poor sorghum establishment in the no till sorghum planting in the mixed pastures. Cavalcade makes an ideal mulch species because of the speed of breakdown of mulch in the early wet. Dual plus Atrazine gave the best results and the main damage was due to birds eating seedlings. When space occurs due to poor plant populations, weeds become a problem. Narrower row spacings in sorghum may also help with weed control, because of the shading effects of the sorghum.