Final report

Pardoo Beef Corporation Collaborative Innovation Program Innovation Manager

Project code: P.PSH.0829

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Date published: 30 June 2020

PUBLISHED BY
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NORTH SYDNEY NSW 2059

This is an MLA Donor Company funded project.

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Abstract

Relating to a pioneering Wagyu Beef Production program in the Pilbara of Western Australia, primarily utilising irrigated tropical forages, Pardoo Beef Corporation (PBC) employed a single suitably qualified person designated as Technical Innovations Manager. This person was part of MLA's cohort of Co-Innovation Managers during 2016-2020 which sought to design and deliver innovation strategies and adoption.

The major investment was the irrigated grass; the optimum production of this and its utilisation by grazing and conservation formed the focus of the project. Over three years key issues identified as affecting cost of production to feedlot entry stage were pasture growth and associated quality, together with optimum utilisation by grazing cattle. This recognised the role of grazing management, energy supplementation to cattle grazing tropical pastures and integration with mechanical harvesting of good quality forage. With more than three-fold variation in pasture growth rate associated with climate, maintaining optimum pasture utilisation remained a management challenge. Measuring cattle weight change is emphasised as an integral component of program evaluation.

Fertiliser was a major cost and aspects of plant nutrient supply were investigated and refined. Additional observations and measurements included the performance of Wagyu cattle in grazing and feedlot environments, cattle mineral supply and balance in association with water source, gastrointestinal parasite management, application of satellite imagery to pasture biomass estimation and special requirements for farm management software.

The costs of beef production were identified and reduced but remained relatively high by industry comparisons, at the early stage of this program. The premium price typically associated with high grade Wagyu cattle could justify this higher cost of production, especially with further reduction in costs as input utilisation improves.

Executive summary

Relating to a pioneering Wagyu Beef Production program in the Pilbara of Western Australia, primarily utilising irrigated tropical forages, Pardoo Beef Corporation (PBC) employed a single suitably qualified person designated as Technical Innovations Manager. This person was part of MLA's cohort of Co-Innovation Managers during 2016-2020 which sought to design and deliver innovation strategies and adoption.

The project had many objectives encompassing the entire program “paddock to plate”. The major investment at the early-stage program was the establishment of irrigated tropical grass utilising an eventual 20 pivots by the end of the first development period. Given the innovative nature of this venture, a science-based oversight was seen as adding rigor to this early stage, with pasture production and utilisation together with cattle nutrition identified as key issues.

The principal grass species utilised was Rhodes grass (Chloris gayana). Over three years key issues identified as affecting cost of production to feedlot entry stage were pasture growth and associated quality, together with optimum utilisation by grazing cattle. Quality of the Rhodes grass pasture remained a factor in cost of production, as digestibility of leaf seldom was greater than 60% with ME values of 8.5 to 9.0 as a limit. Any grazing outside the guidelines of leaf availability was associated with lower intake including some stem, further reducing digestibility. With the experience of observing and measuring pasture growth and utilisation under grazing by cattle, a comprehensive Grazing Guidelines document was compiled and became the basis for Rhodes grass grazing management, at least in the coastal Pilbara environment.

Pasture utilisation recognised the role of grazing management, energy supplementation to cattle grazing tropical pastures and integration with mechanical harvesting of good quality forage. With more than three-fold variation in pasture growth rate associated with climate, maintaining optimum pasture utilisation remained a management challenge. Measuring cattle weight change is emphasised as an integral component of program evaluation.

The costs of beef production were identified and reduced but remained relatively high by industry comparisons, at the early stage of this program. The premium price typically associated with high grade Wagyu cattle could justify this higher cost of production, especially with further reduction in costs as input utilisation improves. Extracting robust data in a field situation without a controlled environment could be considered questionable; however, for largely Wagyu-derived genetics grazing unsupplemented Rhodes grass over the hotter months of October to May, an average daily gain of approximately 0.2% of bodyweight was a typical figure, associated with a cost of gain on average of $3.06/kg. In line with published data addition of an energy supplement in the form of molasses to the tropical grass increased ADG and reduced cost to $2.57/kg. It is expected that these costs would increase as fertiliser response and pasture growth reduced in the cooler months; this will be investigated.

Acknowledging the lower cost of weaner production from rangeland calving, farm gate cost of production for 350 kg cattle may be as low as $2.50/kg, reproductive rate and calf weaning weight being the important variables in the rangeland production system. The opportunity to objectively evaluate the entire system has not been available to date but will soon eventuate.
Water, nutrient and soil factors were examined to confirm that production of tropical grasses under irrigation as documented could be considered excellent by environmental audit. Soil water and nutrients applied was largely confined to the top 1500cm soil horizon, except for sulphur, excessive in the water for plant uptake ability.

From an agricultural perspective valuable water attributes were identified, included bicarbonate levels sufficient to maintain soil pH over 3 years with large nitrogen applications and biomass offtake, and potassium, sulphur and magnesium levels worth an estimated $500,000/year. Pasture production costs were calculated as approximately $5000/ha/year: fertiliser $2400, labour $1100, R&M $900 and depreciation $600. With the large contribution of fertiliser to costs a thorough nutrient response trial was commissioned with 10 measurements over 12 months. This guided fertiliser application in the local environment, with considerable financial consequences particularly for fodder production. Further investigation into nitrogen source indicated possible significant loss via volatilisation, certainly a subject for research given the nitrogen fertiliser cost ($1600/ha/year).

Investigation of the mineral status of grazing cattle confirmed selenium, cobalt and copper deficiencies, the latter induced by high plant sulphur levels in association with moderate soil molybdenum levels. Calculated dietary provision of these microminerals via drinking water was shown to maintain excellent tissue levels at low cost.
The opportunity was taken to monitor gastro-intestinal parasite ecology, considered a potential problem with the often remarkably high summer stocking rates (to 13 AE/ha) and constant green pasture. Overall, cattle performance was affected to a transient degree and easily managed. Factors associated with this are discussed.

An interim maize crop indicated the superior input use efficiency of this crop for cattle forage production in the Pilbara environment. Utilising a pilot feeding facility, performance of the Wagyu-derived cattle on a maize silage-based ration (CP 13%, ME 11.6) was measured over the months August 2019 – April 2020. Cattle growth path was restricted to a grower phase, and hence cost of gain higher. With imported concentrate ration ingredients, inevitably more expensive in the remote situation, ration cost remained relatively high by industry comparison. In the cooler months August to December on the ration provided average CoG and ADG were $3.75 and 0.84kg/day respectively. From January to April the figures were $5.03 and 0.76 kg/day, respectively. An assessment was made of the effect of thermal environment; behaviour and performance over the summer months was encouragingly good, particularly in the absence of shade. The restricted cattle growth path associated with less metabolic heat production would have been a factor in this. Signs of thermal discomfort were minimal and confined to the months January to March associated with increased overnight minimum temperatures and increased relative humidity.

Utilisation of satellite imagery and pasture biomass prediction as a guide to pasture grazing management was evaluated. Whilst some unpredictable anomalies were noted the potential for this technology to have a constructive role in intensive tropical pasture grazing was appreciated and further application remains in progress.

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1 Background

Pardoo Beef Corporation agreed with MLA to commence a Collaborative Innovation Strategy program (CISp – later rebranded as Co-Innovation Program) with MLA over a three-year period commencing on 30th October 2016. The focus of the program was to support the development of Pardoo Beef Corporation (PBC) growth strategies in both the domestic and global markets to be achieved via the development of a innovative northern Australian Wagyu production system, a range of innovative products, packaging, processes and value chain concepts that extend from the paddock to the plate.

The collaborative innovation strategies program is innovation strategy development framework for achieving a suite of cross-portfolio innovation outcomes, which directly address the organisation's strategic needs and industry priorities. The program focusses on innovation, not BAU, which may include digitisation, technology adoption, culture transformation and sustainability within the red meat industry

The value of the program to the Australian red meat industry includes;

1. Increased innovation maturity and R&D within partner organisations through long term partnerships
2. Increased performance, culture, capability and collaboration within organisations
3. Elevated practices within the industry through accelerated adoption

The innovation strategy developed as part of the collaborative innovation strategies program is aligned to and integrated into the company's overall business strategy and includes measurable performance indicators which identify the contribution of innovation to the bottom line and benefits the CISp delivered to both PBC and the Australian red meat industry.

Research relating to the novel Pardoo Wagyu production program was identified as limited, largely confined to north-eastern Australia and not addressing amongst other factors the unique cattle breed, feed source and Pilbara environment combination.

2 Project Objectives

Referring to the Pardoo Beef Corporation (PBC) Pilbara Wagyu production Program, it was recognised that the initiative was truly innovative in its scale, location, feed production base and marketing ambition. As such it had the potential to research, develop and demonstrate an alternative beef market for northern Australia. Not surprisingly, in this context there were many unknowns. To identify and address these was the basis of the Collaborative Innovation Strategy program (CISp) with MLA over a three year period commencing on 30th October 2016. The focus of the program was to support the development of the PBC program.

The scope of the innovation strategy to be developed was to include initiatives in the following key business areas:

• Innovation resource planning and people management;

• Operational efficiency;

• Environmental sustainability;

• New products and markets;

• Marketing and market access

• New business systems and models (e.g. value chain innovation; new strategic alliances);

• Supply chain innovation (including areas such as eating quality; information management; supply chain alignment; through chain assurance).

3 Methodology

The CISP resource proposed was breathtakingly simple: utilise a single suitably qualified person designated as Technical Innovations Manager, working under the objectives outlined, to identify, prioritise and develop solutions and outcomes.

The CISp had many objectives encompassing the entire program "paddock to plate", as is commonly referenced in grazing animal meat production. However, it was recognised that it would be a number of years before cattle were conceived, born and raised on the paddock to a point of departure for their journey to plate. The major investment in progress was the irrigated grass, and this was the source of an increasing number of unknowns. Not the least of these was, what were the key factors unique to the coastal Pilbara environment to make this a viable Wagyu production business in the short-, medium- or long- term? Integral in this was defining the pasture growth and quality and ability to provide the required nutrition for a specialist meat production program.

With this in mind the CISp objectives were limited largely to the pre-farm gate stage; towards the end of the 3-year period cattle were progressing to southern feedlot for finishing, and within a year impacts of management in the Pardoo environment will become apparent, enabling further refinement of management if indicated.

Although transiently familiar with the PBC pivot grazing, the formal start of the position on 17 September 2017 and first week at Pardoo gave the opportunity for the Technical Innovation Manager to become familiar with the real operation in the context of the grand business plan. (It is sobering to reflect on the observations of the initial weeks of the project, in that issues perceived as priorities then remain yet not fully resolved).

3.1 Preliminary data collection and consideration of potential issues arising

Early in the project results of soil and plant analyses available were evaluated, and further targeted sampling was commenced. Also evaluated was analysis of the irrigation water sourced from the Wallal artesian aquifer. Weather data was monitored with a local DPIRD weather station.

Pasture growth and quality had improved in the year prior to the project with input from Department of Agriculture and private agronomists; it was perceived, however, that the absence of any local nutrient response trial data would have resulted in inability to benchmark production responses and provide accurate recommendations, particularly incorporating economic parameters. The largely monoculture of Rhodes grass, one of few species permitted by statutory authorities, clearly grew well in the environment, but soil and plant critical nutrient targets could not have been derived.

3.2 Ongoing data collection and prioritisation of activities

As cattle numbers increased and cattle growth was measured, additional data were recorded for analysis of key parameters. Over the three years of the project the magnitude and priority of various production issues were defined and actively managed within the context of the resources. Given that cattle health and welfare were paramount and maintained as priority, production issues were approached bearing in mind economics, practicality, and sustainability.

The Results section of this report deals with the issues considered as being most significant. The sub-headings detail the observations, conclusions, management considerations, economic impacts and research carried out for each.

4 Results

4.1 Grazing management of Rhodes grass

Introduction

The preconceived Pardoo Wagyu production program was based primarily upon the grazing of irrigated Rhodes grass (*Chloris gayana*). Successful establishment and favourable growth of this species under irrigation had been recorded in the Pilbara, initiated largely by the need to dewater open-cut mines and utilise the water to grow fodder. For ongoing local nutrition of cattle, grazing was seen as a natural option, as elsewhere, particularly in Australia and New Zealand, where grazed pasture is considered likely to be the cheapest source of feed.

Most of the information relating to grazing management by cattle has involved C3 species in temperate climatic areas, typically grazed by dairy cattle. The principles are applicable to tropical C4 pastures, but have not been so thoroughly investigated – perhaps because dairy cattle are not so commonly located in tropical areas in Australia.

In a pasture-based system of animal production, profitability is strongly linked to utilisation of pasture. Although considered cheap, if not well managed an increasing amount is wasted and then pasture becomes an expensive source of feed.

Key criteria for effectively grazing C3 ryegrass-based pastures (Fulkerson and Donaghy 2001) and C4 kikuyu grass pastures (Fulkerson et al. 1999) have been proven and are widely and successfully employed. They are primarily plant-based but account also for cattle nutritional requirements.

Whilst there is a classic body of innovative research dating from the 70s on cattle grazing Rhodes grass dairy pastures in Queensland (for example Stobbs 1973, Benvenutti et al. 2009, Pembleton et al. 2009) the fundamental factors of utilisation and economics were not resolved; Ehrlich et al. (2003) did demonstrate effects of a number of grazing strategies on dairy cow liveweight and milk production but concentrate was a significant part of the ration and liveweight changes over the trial were substantial, making conclusions limited.

Background

At the start of this project (September 2017) there were 6 pivot-irrigated Rhodes grass pastures each 40 ha established a year earlier, with a further 6 of 50 ha being established July to October 2017. The first 6 were subdivided for grazing into 8 sectors of 5 ha; the latter 6 into 4 sectors of 12.5 ha. In 2018, 6 pivots were added (40 or 50 ha, not subdivided – intended for crop production and pasture harvest for conservation) and a further two (40 ha) in 2019. In total 20 pivots with an area of 890 ha.

To manage the pasture it was attempted to acquire cattle at a stage when pasture first required grazing, with nutritional requirements judged in balance with pasture growth so as to manage and utilise the growing asset.

The story begins.

Factors found necessary to be aware of and manage for grazed Rhodes grass pasture in the Pilbara

An objectively planned area and amount of pasture allocated per animal at each new grazing opportunity is a common factor in optimum utilisation of grazed pasture, with consideration for cattle intake. Ideally a one-day allocation, based on a feed budget and cattle requirements, of a leafy pasture associated with maximum bite size will generate optimum cattle performance and pasture utilisation with minimum pasture damage. A maximum time in any one grazing allocation of 3 days was attempted wherever possible. However, it was seldom accomplished, for a multitude of reasons.

With the experience of observing and measuring pasture growth and utilisation under grazing by cattle, a comprehensive Grazing Guidelines document (Bell 2020) was compiled and provided to staff in association with field walks and pasture sampling. This resource became the basis for Rhodes grass grazing management.

The salient components of the grazing guideline follow, in order that the reader may appreciate what was concluded by the author to be a grazing program likely to be associated with optimum, sustainable grazing of Rhodes grass pastures in the coastal Pilbara environment, taking into account cattle performance and pasture quantity and quality.

Grazing Rhodes grass pastures

Correct grazing management of tropical pastures is required to get the highest possible performance from cattle, and to maintain the pasture in a productive state. This is essential as irrigated pastures are a relatively expensive source of cattle feed and optimum utilisation is important.

Each pasture species is different in growth habit and must be managed accordingly.

Characteristics of grazed Rhodes grass and other tropical grass pastures

Following grazing or mechanical defoliation, there is initial leafy growth from the level to which the pasture has been reduced.

- Leaf emergence at a rate dependant on temperature and day length, at intervals over a range typically in northern Australia from 3 to 10 days
- An increasing proportion of stem in the sward as regrowth time elapses

- Although pasture height and mass increase, the bulk density, or weight of dry matter per volume of the sward commonly decreases
- Variable height and density, the major cause of variation being contamination by cattle excreta, mostly dung
- It is important to recognise the variable features of the pasture. Standing out are pasture clumps - taller, more mature areas ("EA", excreta or dung- affected areas). These typically occupy 15 to 25 % of a pasture, the proportion increasing with time since pasture "resetting" (See Tools).
  The pasture between these laxly grazed clumps, or interstitial areas ("IA"), is shorter and is the area favoured by cattle.
- The term Feed On Offer (FOO) describes the amount of pasture dry matter available to the animal and is assessed by estimating the pasture dry weight/ha. It is expressed as kilograms of pasture dry matter per hectare (kg DM/ha - see "Tools")

Cattle grazing characteristics on tropical grass pastures

The intake of animals at a particular time is largely determined by the leaf offered per unit area irrespective of the number of animals grazing. Thus, leaf yield, and to a lesser extent pasture density and leaf to stem ratio, provide a better expression of pasture supply than grazing pressure (cattle per hectare at any given time).

Cattle strongly prefer and select for leaf, and leaf that is younger and therefore more digestible and palatable. It is recognised that the major factor associated with cattle growth rate is leaf bite size, and recognition of this will greatly guide decisions in grazing management and good allocation of grass to cattle. Bite size can be well described as the pasture mass per unit area effectively covered by one bite. Simple yet profound.

The highest leaf density is typically in pastures around the 3- to 4-leaf stages of growth. The top horizon of such a pasture will have more leaf rather than stem.

Short pastures may have good quality (digestibility) but bite size is inadequate for a high daily intake. As pastures become older and taller leaves may be large and long but density is low and cattle intake per bite reduces. There is also more stem to deter and impede grazing of leaf, and leaf quality reduces with age.

Cattle select the more digestible shorter pasture between the EA clumps. If left to graze pasture IA below the critical level (see grazing guidelines) they will degrade this area, often uprooting plants and stolons which can involve many plants. They laxly graze the top of the clumps, which become more pronounced over time.

Grazing guidelines

For any grazed pastures, best utilisation is achieved by some form of intermittent grazing, the principles of which are:

- Introduce cattle before the grass 4-leaf stage, or 2500 kg/ha FOO. *Remember all guidelines refer to the pasture in the interstitial areas (IA).* Leaf canopy height and FOO will be variable with seasonal growth but may typically be 20 – 30 cm and 2000 – 2500 kg/ha FOO respectively.
- The shorter the period of grazing the less wastage and better utilisation.

- A grazing period of one day is ideal but seldom achievable in practice; three (3) days should be considered a maximum.
- The rate of regrowth from controlled grazing or resetting to the desired FOO will vary greatly with season, for example in coastal areas of the Pilbara 12 days in summer months to 45 days in the winter.
- *With the large variations in pasture growth rate, it is essential to recognise and plan for often rapid changes in carrying capacity.*
- Know the cattle requirements in dry matter (DM) per day.
- Allocate the pasture to provide this, *by estimating available leaf DM in the top pasture horizon of the pasture interstitial areas, as cut (see Tools). The pasture in IA is leafier, more digestible and favoured by cattle. Remember IA is usually less than the whole pasture area, depending on time since resetting.*
- Maintain a leafy component at the end of grazing to allow rapid recovery. Minimum FOO 500 kg/ha and or 5 cm above the stem level. This refers to IA, from which cattle must be removed although EA still have high FOO, possibly 2000 or greater kg/ha. In this case the pasture would require resetting.

Tools

Cattle requirements

It was estimated that cattle can eat about 2.2-2.5% of their bodyweight/day of typical irrigated Rhodes grass pasture leaf, based on the attributes of fibre, as measured by Neutral Detergent Fibre (NDF, %) and digestibility (DDM, %). Cattle weight gain will vary with breed and weight, but as an approximation for northern cattle with some *Bos indicus* content, 0.25% of bodyweight/day weight gain could be expected. Regular weighing is recommended. The equivalent daily weight gain for Wagyu cattle might be 0.2% of bodyweight.

Pasture quality

Ideally pasture leaf should be tested at a feed analysis laboratory to document important feed attributes, the most relevant being energy as indicated by DDM and ME. Crude protein (CP, %) level is normally more than adequate for intake as governed by DDM and NDF. Typical feed analysis over the years is summarised in Table 4.1.1. It refers to leaf, being much of the diet selected. Whole plant with stem was lower in quality.

Table 4.1.1: A summary of Rhodes grass leaf feed quality analyses - Pardoo 2018-2020

	CP %	ADF%	NDF%	DDM%	ME MJ/kg
Typical (range)	13 (8 – 23)	31 (21 –33)	65 (50 – 70)	58 (56 – 62)	8.3 (7.9-9.0)

These results were from chemistry with digestibility tested by pepsin cellulase method, corrected for in vivo using linear regression to known cattle in vivo standards.

It is pertinent to note that significant variability was recorded between testing houses and methods, most commonly for feed digestibility. This was consistent across years when sub-samples were tested by more than one source. Most feed testing laboratories utilised NIR techniques with calibrations for the attributes tested, unless requested otherwise. The expense of chemistry would be a deterrent for many. As a general recommendation pasture testing should be carried out by the same source, and caution employed in comparing results from different laboratories.

Pasture quantity

The quantity of pasture in a paddock is estimated in kilograms of dry matter per hectare, (kg DM/ha and expressed as Feed on Offeror FOO).

FOO represents the amount of pasture available to the animal and is assessed by estimating the pasture dry weight/ha (kg/ha). By its influence on bite size it is the major factor governing cattle performance at any given time.

To estimate this with sufficient accuracy to manage cattle intake, a visual estimate by an experienced manager can be made following calibration with actual pasture cuts, aided by photo standards of a variety of pasture types. Combined with this is an awareness of seasonal influences on dry matter.

The cuts are made at the junction between dead leaf and stem and/or the clear live and dead stem height which represents a barrier to grazing. This may be close to ground level as can occur in winter, or as high as 15 cm where pastures have become more mature. The level to which pastures have been reset is evident from a horizontal stem layer and is the level at which to make a calibrating cut. From this level fresh pasture emerges and is available to the cattle.

A convenient paddock pasture DM estimation

1. Consider the variations across the paddock
2. Situate a quadrat (50 x 80 cm) at what is judged an average of the pasture type you are estimating
3. Cut to litter/dead stem height removing green material only
4. Weigh green pasture
5. (a) October - April, assumed pasture DM 20%:
   Kg dry matter/ha = green weight in grams multiplied by 5
   e.g. 300 g green = 1500 kg/ha DM

   (b) May - September, assumed pasture DM 25%: multiply above by 6.25

   e.g. 300 g green = 1875 kg/ha DM

A quadrat can be made from 25mm PVC pipe and joiners, and a Ryobi™ garden shearer is very convenient for cutting. Most kitchen scales can be used to weigh pasture.

Pasture resetting

Resetting refers to mechanical removal of the clumps, which becomes essential after two or three grazing cycles, by mowing or mulching to approximately 10 cm.

When resetting pastures, varying amounts of ungrazed material are removed. This comprises pasture which may be trampled and excreta-contaminated, laxly grazed clumps, rejected uprooted pasture plants including stolons, and rejected stem.

If the material cut is of small amount it may not be necessary to remove it from the fresh pasture. If judged as excessive, however, to the degree that too much pasture is blanketed, the dead material should be removed, for example by raking and baling, and discarded if of poor quality as feed, as is often the case.

In the case of mulching the grazed pasture, where the material is cut into small lengths and deposited back, it is important that the amount is not excessive as the resultant litter will act as a physical and nutrient barrier, as well as under warm conditions provide an environment favourable for pathogenic fungal growth.

The following points are additionally highlighted as further background to the complexity of maintaining optimum pasture utilisation by grazing cattle in a commercial program.

- Stem growth in Rhodes grass was an ever-present problem in grazing management. Adequate leaf presentation, considered to be 1500-2500kg/ha, was frequently accompanied by an excess of stem, largely selected against by grazing cattle as well documented. This selective grazing resulted in lower intake and more pasture damage through walking, especially if grazing an area extended for 3 days or more. Even with short regrowth intervals of 14 days or less, as in the summer, stem production was clearly an impediment to grazing. Fig. 4.1.1 demonstrates the inevitable increase in stem levels as Rhodes grass biomass increases; recognising the cattle grazing selectivity against stem would propose that pastures be grazed at biomass of 2500 kg/ha or less.
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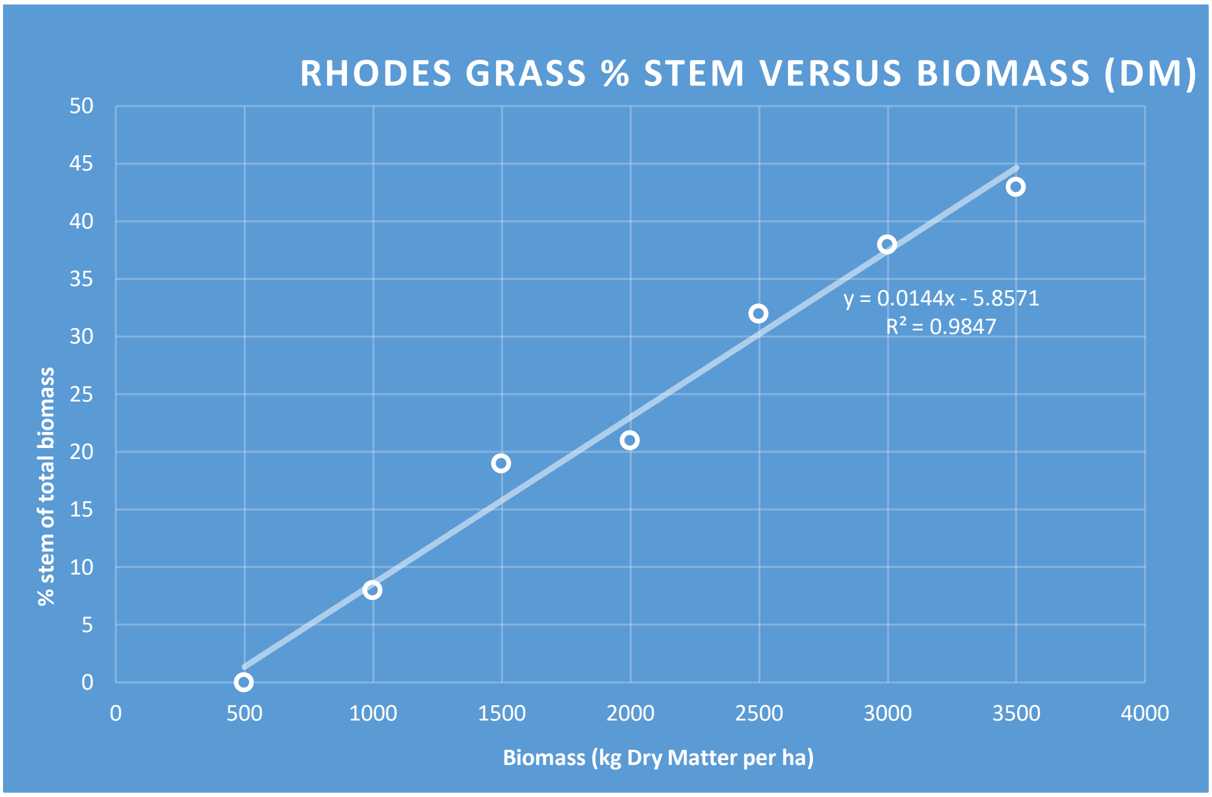

Figure 4.1.1 Rhodes grass % stem versus biomass DM Broome April 2020

- The necessity to graze at shorter intervals, to retain pasture quality, was inevitably associated with a period of less pasture leaf area for light interception and overall lower pasture growth rates (compared for example with the pasture managed for conservation growing to 4T DM/ha or more). Canopy light interception was frequently estimated to be less than 30% where plant density was low for any reason - with 95% being desirable. Water and fertiliser, particularly nitrogen, use in these circumstances became less efficient (Cowan et al. 1995). Table 4.1.2 demonstrates relative pasture growth rates over a one-month regrowth period in September - October, a time of moderate maximum temperatures. Included are leaf proportions at each stage.

Table 4.1.2 An example of relative weekly growth rates of Rhodes grass under grazing management

	Days			
	0 - 7	8 - 14	15 - 21	22 - 28
Est. GR kg/ha/day	15	75	100	200
Est. yield kg/ha/week	105	525	700	1400
Est yield kg/ha over combined period	105 (1 week)	630 (2 weeks)	1330 (3 weeks)	2730 (4 weeks)
GR as calculated kg/ha/day over combined period	**15 (1 week)**	**45 (2 weeks)**	**63 (3 weeks)**	**98 (4 weeks)**
Leaf GR kg/ha/day (leaf %)	15 (100%)	64 (85%)	75 (75%)	120 (60%)
Leaf yield kg/ha/week	105	446	525	840
Leaf yield/interval	105 (7 days)	551 (14 days)	1076 (21 days)	1916 (28 days)
Measured leaf GR kg/ha/day over combined period	**15**	**39**	**51**	**68**

- A common feature of most grazed pastures after one or more grazing periods was the variable height and density of the pasture sward. The major cause of variation was contamination by cattle excreta, mostly dung. Unless the pasture was mechanically “reset” - mowed (“topped”) or mulched after each grazing the residual mature pasture associated with the excreta was selected against at subsequent grazing, with more stem and older leaf. These areas could typically amount to 15 to 25 % of a pasture if ignored.
- The pasture between these laxly grazed clumps being more digestible was always preferentially grazed by cattle. This could have unforeseen consequences for grazing management, in that managers would estimate pasture available on the basis of the visually prominent clumps – which were actually avoided by cattle! A result could be severe overgrazing of the interstitial areas with reduced cattle performance and pasture damage.
- Apart from excessive plant grazing, a most unfortunate consequence was plant loss associated with uprooting of rooted stolons. Stolons may produce prolific tillering at the nodes but rooting was often unsuccessful, being slow and deficient. This was very likely associated with high soil temperatures and surface drying between irrigations. A short regrowth period to maintain pasture quality did not help.
- Root development was very commonly inadequate to anchor the plant when being grazed. Uprooting seemed to take place when grazing was at or below 10 cm when prehending stem as well as leaf. The strength of the higher tensile stem resulted in the whole plant being uprooted rather than sheared off in the bite gathering process. In addition, unanchored stolons can become elevated with a growing sward, the effect being to present as an unstable sward structure for grazing. Prehension by grazing cattle was difficult, a long stolon with associated tillers being detached and often discarded. Some isolated counts of dead uprooted plants in February 2019 are recorded in Table 4.1.2. Also see Fig.4.1.3.

Table 4.1.3: Examples of Rhodes grass plant uprooting summer 2018/2019

Pivot	Rhodes grass variety	Uprooted plants/m^2
3	Katambora	75
4	Reclaimer	60
7	Reclaimer	42
8	Callide	37
9	Reclaimer	48

The period over which the counted plants were uprooted could not be estimated. The damage in this case had been observed over at least the prior 5 months.

Figure 4.1.2: Interstitial areas uprooted plants and stolons Rhodes grass.

Table 4.1.4: 2018/2019 example of stocking rate, required pasture, estimated pasture growth rate required at 50% utilisation and summary of Pardoo field measurements 2018-2020.

Month 2018/2019	AE/ha month average	Pasture required Kg/day*	Necessary PGR pasture growth rate kg/day*	Summary of PGR kg/day estimates
August	3.9	23.4	47	80
September	4.8	28.8	58	110
October	5.7	34.2	68	130
November	12.0	72.0	144	150
December	13.4	80.4	161	160
January	11.6	69.6	139	160
February	10.8	64.8	130	160
March	9.5	57.0	114	160
April	7.1	42.6	85	100
May	6.8	40.8	82	80
June	4.9	29.4	59	70

July	3.8	22.8	46	60
AVERAGE 12 months	7.9		94	

*Assumptions: pasture 60% DDM 9 MJ ME, AE requirement 55 MJ/day, 6 kg pasture DM/day/AE

- The rate of change of pasture growth between seasons proved very difficult to manage. Pasture growth rates under grazing were difficult to accurately measure, being influenced by so many variables. An example of actual stocking rates over a 12-month period give some idea of likely pasture growth variations (Table 4.1.4). Using the pasture requirements of the standard animal unit equivalent (AE), (McLennan et al. 2020), required pasture intake and pasture growth assuming 50% utilisation are calculated. The amplitude of pasture growth is probably less than estimated here with winter utilisation higher. Also, as an observation, pasture growth rates could be expected to be similar over the November to March period.
- From October to November growth rates could potentially double. If pasture was not grazed at the planned time a two-day delay would prove unmanageable unless it could be harvested for conservation. Pastures could lodge and be trampled and very poorly grazed, and a heavy layer of rotting litter remain to physically suppress new plant growth, and nutritionally limit pasture growth by acting as a nitrogen sink. The enormity of the situation can be appreciated when in one week another up to an extra 1000 cattle might be necessary to maintain pasture control. For example, delays in arrival of expected cattle and/or inability to mechanically harvest resulted in many pivot pastures reaching a stage of maturity and structure such that losses of amount and quality were inevitable. With heights exceeding 100 cm and biomass Dry Matter (DM) greater than 5000kg/ha cattle grazing would lead to severe trampling and destruction from the time of introduction and loss of 70% of the growth. Lodging may also take place to the extent that mowing became time consuming and in cases impossible.
- There was an unavoidable imperative to combine mechanical conservation with grazing, on account of the rapid changes in pasture growth rates between wet and dry seasons. This brought with it a conflict in paddock size construction, as smaller subdivisions favoured better grazing management and pasture utilisation, whereas it was a considerable disadvantage for necessarily large machinery operation. Portable electric fencing would seem the only logical alternative, and its use encouraged.

- Fungal disease

  It was observed in the summers of 2018 and 2019 that Rhodes grass pastures on a neighbouring pivot irrigated pasture were severely affected by fungal disease, in the worst cases 90% of growing leaf and stem being killed. The cause not conclusively diagnosed but *Fusarium* and *Phytophthora* spp. were implicated. Fungicide treatment was anecdotally successful in restoring the pasture.

  Observations at the Pardoo pivot pastures over the 2019-2020 summer indicated that small areas of pasture were similarly affected. Interestingly, in mixed Panic and Rhodes grass pastures only Rhodes grass was affected. No treatment was applied, and pastures overall had no discernible reduction in carrying capacity, although this could not be verified. Rhodes grass strongly repopulated the denuded areas some months later.

  In the case of Pivot 2, with a large proportion invaded by the weeds Feathertop Rhodes grass (*Chloris virgata*) and Purple top Rhodes grass (*Chloris inflata*) following a reseeding attempt in September 2018, it was noticed over summer that the weed had died over 80% of the area, with no apparent loss of health and vigour in the associated Panic grass. The symptoms were like those in the case of the fungal disease affected sown Rhodes grass pastures. This was beneficial in that the productivity of the pasture was restored.

Features and observations relating to Panic grass

- In mixed Rhodes grass and Panic grass pastures, the tufted growth of the Panic acted to protect it against overgrazing and uprooting.
- In May 2017 Pivot 1 was sown to a mixture of one third of each of Rhodes grass, Lucerne and Panic. These pasture species were all represented through winter and spring until in late November when in a quite short time Panic became more than 80% of the available pasture. Lucerne had almost vanished and by mid-2018 could not be found apart from an odd plant or two. The pasture composition has persisted and by mid-2020 Rhodes grass was a very minor presence and contributor; essentially it was a Panic pasture. This pasture has performed very well since, being consistently better grazed and of higher feed quality, related to more leaf and less selectivity by cattle when grazing. Gradual increase in the stem layer was rectified periodically, typically when it had reached 20 cm or more, by cutting for hay at 10-12 cm.
- In mixed pastures where there was Rhodes grass death from a presumed fungal disease, Panic was not affected, and increased in proportion as a result.
- Purple discoloration of a proportion of plant leaves in winter was more noticeable for Panic than Rhodes grass (Fig. 4.1.3). This anthocyanin pigmentation as an indication of cold stress typically was present from June until September. Leaves were observed to have purple coloration, either generalised or in stripes lengthwise. It was not observed in oat plants over-sown into the tropical grass pasture, and it was assumed that the tropical pastures were exhibiting natural symptoms of cold stress.

Figure 4.1.3: Purple discolouration of tropical grass plants, Oat plants normal same pasture.

- Compared with Rhodes grass, Panic was affected to a much less degree in the locust plague February to April 2018. Leaves were chewed but the plants were not reduced to mere stumps as were Rhodes grass plants.
- Panic tufts generated by mature stems tended to become larger and higher (greater than 15 cm). Grazing below this barrier ceased, although new tillers did safely develop within the tuft. If left long enough tillering occurred on stem nodes at sometimes considerable distances from the ground (30 to 50 cm). This was not ideal as presentation to cattle; it was easily managed when tuft height was reset as described.

- The somewhat unexplained pale green/yellow appearance of Panic pastures in comparison to Rhodes grass was examined. It could be noticed during early regrowth following grazing or mowing. Nitrogen deficiency was suspected but not confirmed by plant test.

Observations relating to the effect of heat load for cattle grazing irrigated tropical pastures in the Pilbara

Subjective and objective observation of cattle over the 2018/2019 summer “wet season” (November 2018 to March 2019) indicated that Wagyu cattle consistently displayed transient symptoms of heat stress. These signs were less evident or not apparent in tropically adapted *Bos indicus* cross cattle.

All Wagyu cattle: clustering around water (troughs, puddles, pivot sprinklers in operation), shade seeking, limited day time grazing unless in mist from pivot sprinklers. Panting scores 1 – 2.0.

Weaner Wagyu cattle: as above plus significant proportion panting scores 1 – 2.5.

Further evaluation of the effect of the Pardoo climate on Wagyu and Wagyu cross cattle was maintained in subsequent summers. Currently this includes comparing weather measurements and heat loads predicted for grazing as well as feedlot conditions.

4.2 Nutrient management and soil factors

Apart from regular soil and plant tissue testing over the course of the project in connection with pasture health and production, opportunities were taken to record soil factors of current and long-term consequence.

Initially there was recognisable overwatering, exacerbated by maintaining summer watering levels 2017/2018 through into the winter, at which time pasture water use was very much reduced by a combination of lower temperatures, severe locust damage and phosphate deficiency.

In August deeper sampling indicated excessive soil moisture beyond 200cm. As an indication a 2.2m 12mm rod could easily be pushed its full length into the ground. (Fig. 4.1.1) The soil water features were common on all pivots.

Figure 4.2.1: Demonstration of excessive water application August 2018.

Rhodes grass root depth

The face of a soil pit dug in August 2018 revealed a healthy and substantial root mass to at least 130 cm, indicating the capacity of the pasture to access water and nutrients to at least this depth. This gave confidence to continue the modified irrigation schedule, in particular reducing amount and frequency of water applied. Soil water to a depth of 1.5 to 1.8 metres was considered satisfactory to provide a buffer for plant use without leading to leaching losses beyond root depth.

In August 2019 strong root presence to a depth of 200 cm was observed in soil pits dug in Pivots 7 and 8.

Figure 4.2.2: Rhode grass roots to 130cm P4 C1 August 2018

Mineral levels in irrigation water: annual soil additions, nutrient balance and economic significance

An early stage review of water analysis data indicated an issue of potential significance to production: significant levels of sulphur as sulphate, potassium and magnesium in the water would had relevance to fertiliser application with regard to ongoing topdressing requirements, and potential antagonisms in plant uptake (Table 4.2.1).

Table 4.2.1: Irrigation water selected nutrient levels, annual soil additions, nutrient balance and economic significance.

Nutrient	Average (range) mg/L Bores PB1 – PB10	Average applied via irrigation kg/ha/year @ 17ML/ha	Satisfactory pasture level (%DM)	Annual requirement/ha (kg) @40T/ha DM pasture removal	# Potential value/ha/year in water ($)
Potassium (K)	6.5 (5.9-7.7)	110.5	1.5	600	$127
Sulphur (S)*	31 (21-47)	527	0.20	80	$72
Magnesium (Mg)	15.4 (9-28)	262	0.15	60	$150
Boron (B)	0.2 (0.17-0.22)	3.4	5 (mg/kg)	0.20	
Phosphorus (P)	<0.01	n/a			
Nitrogen (N) as NO3	<0.5	n/a			

* Sulphur 33.3% of sulphate as measured

Estimated nutrient value $/kg landed Pardoo

- K $1.35
- S $0.90
- Mg $2.50

As is referred to subsequently (4.3 Fertiliser response trial; 4.5 Water and soil factors influencing cattle nutrition) the mineral content of the water had significant production and economic effects, mostly beneficial, on pasture and crop production. For example, prior to the project sulphur fertiliser was being used, not recognising the water content. Changing potassium source from potassium sulphate to potassium chloride reduced potassium cost by between $1.00 and $1.30; for the total area this reduced cost by more than $250,000 /year.

Any concern regarding chloride levels in the amount of muriate of potash applied were considered negligible; chloride in fertiliser amounted to approximately 220 kg/ha/year, with more than double this removed in plant offtake. (In perspective, the water source applied more than 3000 kg/ha/year).

In addition, it is expected that bicarbonate levels (150 to 170 mg/L) would have acted to counter the expected increase in soil acidity associated with the high production; soil pH had not changed measurably over the 3 years of the project.

Both water and fertiliser application demonstrably improved in efficiency over the three years, the latter particularly in response to the nutrient response trial which gave some confidence to fertiliser use. Skilled management including soil moisture monitoring contributed to this.

The effect of the apparently excessive water on reducing soluble nutrient soil levels was hard to establish, although clearly a possibility. The weekly provision of nitrogen (N) and regular provision of potassium (K) and sulphur (S), associated with significant K and S levels in the bore water (referred to elsewhere) would clearly act to replenish soil levels if leaching was occurring. Irrigation was revised with reference to readings from soil moisture probes installed by DPIRD, bore meter readings, water application as measured at ground level by catch cans, and direct soil examination and measurement with spade and sampler. Soil moisture as observed was demonstrably improved and continued to reduce at depth.

Investigation of records indicated that the application of MAP as the source of phosphorus had highly likely been omitted since late 2017, with a few exceptions which clearly confirmed P deficiency.

Apart from Pivot 10 and Pivot 12, which fortuitously received 50 kg/ha MAP on April 16 with an oversowing with oats activity, and Pivot 2 lucerne with a documented application of 100 or 200 kg/ha 0n 22 December 2017, P levels on half to two thirds of the remaining pivots were catastrophically low – essentially of the order of that in virgin Pindan.

It was concluded that severe phosphorus deficiency had been the major cause of poor pasture growth since the abatement of locust grazing in late April. Until P was applied all other nutrients applied were essentially ineffective and wasted.

The phosphorus levels on pivots were raised by MAP topdressing between 16 and 22 June. Faulty topdresser calibration in this exercise resulted in well-defined fertilised areas receiving at least 85 kg/ha, at the expense of the remainder of the area which received an insignificant amount. In fact, this became an effective demonstration trial (Fig. 4.2.3).

Figure 4.2.3: MAP topdressed pasture strips standing out from missed areas.

Table 4.2.2: Effect of phosphorous application on soil and plant P levels following P application to deficient pasture.

Pivot	Date	Activity	P Soil ppm		P Plant %	
			Before	After	Before	After
10,12	20.06.18	50 kg/ha MAP 16.04.18 (65days)	1	5, 8	0.1	0.22
4	12.07.18	85 kg/ha MAP 20.06.18 (32 days)	2	4	0.1	0.36

Irrigated and fertilised pastures compared with virgin soil

In connection with soil survey work, in August 2019 deep soil pits to 5 meters were dug across the pivot area. The opportunity to obtain nutrient levels after 2 years irrigation and fertiliser application on Rhodes grass pastures was taken. Samples at a range of depths to 5 meters were obtained from pivots 7 and 8, as well as a virgin site adjacent to Pivot 8. (Table 4.2.3).

Comments:

The lower subsoils had a low to high phosphorus adsorption rating indicating that phosphorus should not be readily leached from the irrigation areas.

Significant observations:

1. Soil pH, both topsoil and subsoil, remained at a favourable level for agriculture; if anything, it had increased marginally over two years of irrigation. This may well be as a result of irrigation water with pH consistently above 7.0 with significant bicarbonate levels.
2. Nutrient levels apart from sulphur have remained largely unchanged, Potassium decreasing if anything. This would be a function of a satisfactory balance between plant use and fertiliser application. As mentioned regarding the fertiliser trial conducted, there was a minor or inapparent response to K presumably with the significant virgin soil levels and irrigation water content (Table 4.2.3).

3. The increased sulphur soil levels were in response to the high S levels in the irrigation water. That they are maintained to 400 cm or beyond indicates water drainage at some stage. The levels are far more than possible plant uptake.

Table 4.2.3: Topsoil and subsoil chemistry of virgin and 2-year irrigated pasture sites.

Soil horizon (cm)	Chemistry	Virgin soil	Pivot 8	Pivot 7
0-50	pH(1:5soil:$CaCl_2$)	6.2	6.4	6.6
	P (mg/kg)	1	1	1
	K (mg/kg)	47	37	84
	S (mg/kg)	3	16	9
50-100	pH	5.7	6.6	6.7
	P	2	1	1
	K	86	70	64
	S	2	16	10
100-200	pH	6.3	6.3	6.7
	P	1	1	1
	K	66	37	52
	S	2	16	16
200-300	pH	6.1	6.2	7.3
	P	1	1	1
	K	47	27	48
	S	5	12	4
300-400	pH	6.4	6.5	
	P	1	1	
	K	40	19	
	S	3	17	

4.3 Plant nutrients trial fertiliser response

It was recognised early in the project that fertiliser use constituted the most expensive ongoing input to the pasture production program (approximately 50% of costs). The fertiliser program was based upon general predictions from a variety of sources and had not been thoroughly scrutinised or calibrated against any trial data in the Pardoo Pilbara environment.

Preliminary work (DAFWA 2017) had indicated pasture symptoms indicative of nutrient, most likely nitrogen, deficiency. By May of 2018 pasture and soil tests indicated significant deficiencies of major nutrients, with the exception of sulphur. These tests were from areas of poor pasture growth.

In association with fertiliser company CSBP a thorough nutrient trial was established by November 2018. The site was a newly established pivot pasture, a sector being fenced off and 16 plot treatments imposed, each with 3 replicates. The plots were 20 m by 2 m.

Treatments

The design was 5 rates of each of N, P, and K, including 0 (Table 4.3.1). In testing each nutrient, luxury rates of the other nutrients were included. As referred to, high water S levels provided surplus nutrient and a S response would not be expected. The fertiliser levels were applied at the start, and after each sampling. The plots were measured over 10 growth cycles. After each sampling the whole site was mowed to 12 cm and vegetation removed.

Table 4.3.1: Fertiliser nutrient (N, P and K) application levels tested.

Nutrient rate (kg/ha)	N	P	K
	0	0	0
	20	5	12.5
	40	10	25
	80	20	50
	160	40	100

Results - summary

- 10 cuts/year
- Strong response to N, not peaking at 160 kg/ha/harvest
- Moderate response to P, optimum application 20 kg/ha/harvest
- Little response to K. This was most likely associated with K levels considered adequate to marginal in virgin soil, combined with significant K applied in the irrigation water (>10 kg/ha/harvest).
- S response not obtainable due to extremely high levels in irrigation water, in excess of requirements.

See Table 4.3.2.

Table 4.3.2: Summary of plant nutrient trial 2019.

Fertiliser rates Nutrient kg/ha/harvest	Dry matter (DM) T/ha/harvest	Number of harvests	Indicative DM T/ha/year
0 N, 20 P	0.7	10	7.1
20 N, 20 P	1.2	10	12.4
40 N, 20 P	1.7	10	16.6
80 N, 20 P	2.0	10	20.5
160 N, 20 P	3.8	10	37.6

Discussion

In the case of hay production, as simulated by the trial design of roughly monthly harvests, the indicative increases in profit above extra fertiliser were very favourable. Particularly significant was the response at the higher end of the N applications. The magnitude of these was unexpected and interim data being obtained presently indicates possible further economically favourable outcomes from higher N levels.

In time K levels in soil are expected to reduce and a response obtained. In older pivots there was a response in plant K levels to applied fertiliser.

4.4 Comparison between ammonium nitrate and a urea/ammonium nitrate mixture as nitrogen sources for irrigated tropical grasses

Background

Nitrogen was the costliest fertiliser input for the Pardoo irrigated pastures, supplied via irrigation as liquid urea/ammonium nitrate (UAN).

In response to the possibility of accessing AN alone at significantly less cost the pasture response to iso-nitrogenous UAN compared with AN was evaluated.

Methods

Over a 24-day period from 22.12.18 to 15.1.19 on two halves of a 50 ha pivot of irrigated tropical pasture at Pardoo the two sources of liquid nitrogen fertiliser were compared.

Recommended levels of nitrogen, phosphorus and potassium were applied to achieve optimum growth.

The nitrogen fertilisers were delivered through an irrigation approximately weekly to supply 18 units of nitrogen (N) per application (Table 4.4.1). Each treatment was half of the pivot (180 degrees of pivot travel).

Application details:

Table 4.4.1: UAN and AN application details.

	% N (weight/volume)	Rate L/ha	N (kg/ha/week)
UAN	42	43	18
AN	20	90	18

The 50 ha was mowed to approximately 10 cm on 24.12.2018. Measurement were made on 15.1.2019, an interval of 23 days growth. At the end of the trial period 8 quadrats of area 0.4m^2 were cut to 10 cm from each of the treatment areas. Soil and plant tissue samples were taken from random sites across both sites. Analysis of pasture feed was conducted on leaf, stem and whole plant.

Results

A substantial increase in production was recorded from the AN treatment (26%). It appeared that most of this was in the form of stem (Table 4.4.2).

There was no significant difference in soil N, NO_3-N or NH_4-N, or in plant total N between the treatments.

From feed quality analysis there were minor advantages in quality for the UAN treatment, relating mainly to the higher leaf proportion.

Table 4.4.2: Effect of nitrogen source on irrigated tropical grass growth

		UAN	AN
Pasture yield Kg/ha		2533	3203
Growth rate kg/ha/day		110	139
Leaf yield kg/ha (%)		1418 (56)	1313 (41)
Stem yield kg/ha (%)		1115 (44)	1890 (59)
Whole plant	**DMD%**	59.7	57.6
	CP%	11.3	10.4
	NDF%	67.9	70.5
Leaf	**DMD%**	59.5	58.6
	CP%	12.6	12.4
	NDF%	61.1	63.6
Stem	**DMD%**	59.8	58.1
	CP%	8.6	7.5
	NDF%	68.0	70.4

Discussion

It appeared that N availability to the pasture was greater with N provided solely from AN compared with the commonly available UAN product, given that the same amount was applied. This raised the possibility of greater N loss from the urea component, as is certainly recorded under tropical systems. For example Martha et al. (2004) in a tropical pasture recorded an accumulated NH_3-N loss of 45 kg/ha from a solution of urea applied at the rate of 100 kg N/ha, peaking at 13 kg NH_3-N per day over the first 2 or 3 days after fertilisation. This compared with much lower NH_3-N accumulated and peak losses of 13 kg/ha and 2 kg/ha/day respectively when the N source was ammonium sulphate. The significance for Pardoo is unclear, as both soil properties and environmental conditions influence ammonia volatilisation. The results here do indicate, however, that if available at favourable cost the AN product does have an advantage.

With regard to the pasture feed value results, a large component of the greater yield recorded was associated with a higher proportion of stem, with a small concomitant loss of feed value. In practice this would be managed by earlier harvest if quality was a serious issue. In the case of grazing the increase in pasture growth rate would allow shorter intervals between grazing.

4.5 Water and soil factors influencing cattle dietary mineral composition and cattle performance. Copper, Selenium and Cobalt provision to pivot grazing cattle

Introduction

Plant and soil testing early in the project identified the potential for cattle mineral disorders:

- High water sulphur levels resulted in high plant levels of sulphur (S)
- Moderate to high soil and plant molybdenum (Mo) levels
- Declining plant cobalt (Co) and selenium (Se) levels

Blood testing of cattle confirmed the predicted potential effect on cattle health; copper (Cu), cobalt and selenium levels were declining to levels considered deficient, with the potential to reduce productivity.

Copper and selenium can be provided at intervals as they are stored in the liver; however, cobalt is required constantly as it is used by rumen bacteria to make vitamin B12, the compound required by the cattle. It is not stored.

These factors were identified as of immediate importance for cattle health. After considering all issues they were informed by cattle diet and clinical biochemistry and prophylactic dietary supply of each mineral instigated as calculated. This was successful in overcoming any mineral deficiencies, as confirmed by satisfactory improvement in blood parameters.

History

The above three trace elements are all essential for animals. For grasses, of these only the copper is required. In circumstances as existed on the Pardoo irrigated pastures the levels of copper supplied as considered adequate for optimum pasture growth (>5 mg/kg dry matter) were below the 7-10 mg/kg dry matter recommended for cattle (Judson and McFarlane 1998).

It was to be expected that initial soil levels of all three minerals would have been depleted with the high levels of pasture production and mineral removal from the irrigated pasture areas. Occasional high rainfall events as might occur with expected annual cyclones would have further depleted soil reserves.

With regard to copper, three additional factors were operating to reduce availability to cattle:

1. A high level of sulphur as sulphate in the irrigation water, leading to high sulphur plant levels.

The average sulphur level in water from 10 bores was 31 mg/L with a range of 21 to 47 mg/L (Table 4.2.1). In the case of typical annual irrigation (17 ML/ha) the resultant sulphur addition to soil was 527 kg/ha. This had the effect of considerably increasing plant S levels above the 0.20% considered adequate for optimum grass growth; from a series of 26 plant analyses over 3 years the average plant S level was 0.40%, occasionally as high as 0.60%.

2. Moderate levels of molybdenum in the soil, leading to elevated plant levels.

Pasture Mo levels from a number of pivots on average were 2.2 mg/kg, to a maximum of 3.2 mg/kg. Suttle (1998b) provided data to indicate these levels could more than halve Cu uptake even at moderate S levels; with the high S levels Cu availability in green grass reduced from 4% to less than 1%.

3. A pasture diet constantly green and actively growing

Cu in grass hay is two to three times more available than in green grass (Suttle 1998b). Cattle on a continual green grass diet do not have the opportunity to replenish liver Cu levels where dietary levels are marginal.

With regard to dietary selenium, low levels could well have been induced by the high sulphate levels as demonstrated by Pratley and McFarlane (1974); pasture levels of both Se and Co were less than recommended cattle dietary minimums, and cattle blood levels were demonstrated to become increasingly deficient (Table 4.5.1).

Typically, young growing cattle require and respond to a higher level of these minerals; at extreme levels of deficiency there are a range of clinical signs for each. The most common and likely effect, however, is reduced growth rate which is usually unpredictable. A treatment response trial is the most reliable diagnostic test.

For cattle grazing the irrigated pastures there were no observed clinical signs of any deficiencies, and opportunities for trials were limited. Between October 2017 and May 2019 blood samples from young growing cattle indicated a situation of existing copper deficiency and cobalt and selenium levels indicative of increasing deficiencies (Table 4.5.1)

Table 4.5.1: History of Cu, Co, Se and Zn levels in young cattle grazing irrigated tropical pasture.

Date/mob		**Selenium**	**Cobalt**	**Copper**	**Zinc**	**Comments**
	Units	GSHPx U/g Hb	MMA umol/L	Cu mg/L	Zn mg/L	
	Reference range	>30	<1.5	0.6 – 1.1	0.8 – 1.3	
October 2017 PB calving heifers	Average Deficient	125 1/10 Some treated?	1.13 2/10	0.18 9/9		Very Cu deficient. (Pasture 3kg/ha CuSO4).
April 2018 PB calves	Average Deficient	111 2/9	0.16 -	0.86 -	1.30 - #4/9 high	Pasture CuSO4 restored Cu in cattle
April 2018 PB cows	Average Deficient	65 -	0.27 -	0.74 -	1.24 - # 2/8 high	
October 2018 PB weaners	Average Deficient	25 7/9	0.94 -	0.65 3/10	1.42 # 5/10 high	Se deficient. (treated)
May 2019 PB weaners	Average Deficient	456 - Selovin 3 months ago	1.65 5/7	0.45 7/8	0.95 1/8	Cu, Co deficient
May 2019 Light PB heifers	Average Deficient	44 1/8	1.0 -	0.47 6/7	0.97 1/8	Cu deficient
May 2019 sick pen PB weaners	Average Deficient	189 -	1.14 -	0.77 1/4	1.00 -	

It was recognised that cattle grazing the pastures would require supplementation in the most effective, convenient and economical manner. Alternatives for treatment were evaluated taking into account efficacy, cost and convenience. Mustering large mobs of cattle in the regularly hot weather was avoided where possible, cattle welfare and staff labour conditions being considered.

Supplementation options

Selenium

Selenium provision to stock historically was unrecorded but probably haphazard. Levels can be seen diminishing until clearly evident from the October 2018 samples from Wagyu weaners. Treatment of the Wagyu weaners at the time with Selovin®, a long-acting injection, restored levels to a predictably high degree.

Ongoing alternatives available were:

- Long-acting injection yearly
- Selenium pellets yearly
- Selenium fertiliser (Selenium Chip® or Agsel®, 1% Se) at 1.0 kg/ha twice yearly (estimated – no recommendations for a tropical irrigated pasture).
- Water treatment with a soluble Se source (sodium selenate).

Cobalt

As for selenium historical provision to cattle unknown. However, cattle levels adequate but approaching borderline limits till October 2018. May 2019 half (4/8) below recommended level.

Treatment alternatives identified

- Long-acting Vitamin B12 injection. This provides adequate levels for 3 months and would need repeating quarterly.
- Alternatively, Cobalt sulphate could be topdressed onto pasture at a trial rate of 0.25 kg/ha and pasture (and cattle) monitored. This would likely be satisfactory with quarterly application but would need testing. It is expensive.
- Cobalt pellets to cattle yearly.
- Water treatment with a soluble Co source (cobalt sulphate).

Copper

Being required by pasture, copper was applied initially (2016 Stage 1, 2017 Stage 2, 2018 Stage 3) as recommended to establish soil levels considered adequate for plant health and production. Pasture plant Cu levels remained at such levels and Cu seldom applied since establishment.

Reference to plant S and Mo tests indicated that a significant proportion of these were at levels known to bind copper and reduce absorbability in the ruminant animal. These and other factors influencing Cu availability for cattle are discussed elsewhere.

Cu levels in pastures, although adequate for plant production, were in the circumstances deficient for cattle requirements. Supply to cattle was required as an ongoing necessity.

Unlike selenium and cobalt, copper can accumulate to toxic levels in the liver, being expressed as an acute and serious condition. It was necessary to take this into account when supplementing.

In this case of unavoidably high dietary sulphur and molybdenum, the level of copper required in the diet was uncertain; cattle sampling was required.

Treatment alternatives identified

- Copper glycinate long-acting injection 6-monthly.
- Copper sulphate topdressed at 3 kg/ha to pastures, a preliminary amount. Test pasture levels 3 to 4 weeks later to evaluate effect. Aim for plant Cu level to be above 20 mg/kg to manage the sulphur and molybdenum intake. It was not known how long this would be effective, but 6 months was assumed.
- Copper pellets to cattle annually
- Water medication with a soluble copper source (copper sulphate)

Summary

All cattle grazing the irrigated Rhodes grass on the pivots for more than 6 weeks were supplemented with copper, cobalt and selenium by water (trough) addition. A commercial 3-day slow-release dispenser was utilised to reliably supply soluble sources of minerals to cattle via drinking water. This was effective, convenient, and inexpensive.

Appropriate dose rates were calculated and prescribed, and effects monitored by analysis of blood samples. The treatments were uniformly successful in achieving the desired cattle levels. The dose rates were calculated most conveniently by reference to cattle weight; supply was calculated on an amount per tonne cattle liveweight/3 days basis for each mob, 3 days being the approximate dispensing time with the equipment.

4.6 Cost of Production of beef on irrigated Rhodes grass pastures

Background

Wagyu Beef being the planned major output from the grazed pastures, to determine as soon as possible the cost of production (CoP) and factors influencing it were priorities within the project.

Given the early stage of the project – a relatively small number of Wagyu cattle, pivot establishment a major activity, pastures in development, a long lead time until beef was turned off – this could be seen as a diversion. However, it was in fact the most important question to answer, particularly following a review of costs and the indication that assumptions around costs and productivity were identified as being flawed, casting doubt around business profitability.

The clearest indication of one aspect of CoP was to calculate costs of pivot operation and pasture production and utilisation, and link with cattle weight gain over a common period. This was simplest in the case of growing cattle, but less straightforward for breeders.

Cattle production plans were conceived around an initial assumption that irrigated pasture would be plenty and cheap. Early plans including using the pivots for breeding cattle and calf production as well as growing cattle. The former was demonstrated to be feasible, but quickly identified as extravagant and inefficient, not to mention associated with cattle health issues in some circumstances. Hence breeding cattle were relocated to the rangelands on which it was common and established practice with favourable CoP, at least for cattle with some *Bos indicus* component (Rangeland Wagyu calf production in the Pilbara remains to be calculated; it is currently a project).

For a grazed pasture, there are two aspects to CoP – for the inputs supplied, (a) total pasture produced and (b) utilisation. Production under grazing was identified as being very variable in practice with extremes of growth rate and frequent inefficient allocation with cattle requirements. Preliminary grazing guidelines established in early 2018 and refined over the program were seldom adhered to, for a variety of reasons. The rapidity of expansion and availability of cattle for timely grazing was associated with difficulty in managing pastures. Also delaying weight gain estimates was the necessitated frequent mixing and redrafting of mobs, often of differing cattle class.

Methods

Output – cattle weight gain

By mid-2019 pivot number had stabilised and cattle numbers were becoming more predictable; the grazing recording system was maintained with some rigor and opportunities to weigh appropriate indicator mobs of cattle were used to document weight gain, in association with grazing areas and time. Cattle were weighed off pasture at one of two strategically located yards with scales, typically no more than one km from pasture.

Inputs – costs

With stability of enterprise as described, actual annual costs became available.

In summary the costs were identified as in Table 4.6.1 Simply, the categories comprised fertiliser, labour, variable running costs and depreciation. These were calculated on a per hectare basis as per usual pasture-based agricultural systems.

Fertiliser application did vary slightly between seasons, nitrogen application being reduced to a relatively small degree in winter.

To match against grazed cattle production, a calculated daily average cost per hectare of $13.70 was used. Clearly this would vary somewhat across seasons, but in fact was associated quite closely with pasture production. In time it will be possible to more precisely dissect summer and winter costs, but at this stage the costing is informative and can be used to extrapolate across seasons.

Table 4.6.1: Pivot irrigated pasture costs 2019.

Item	Cost/ha/year ($)	Comment
Fertiliser	2400	Major items N, P and K. S in water, not required. Cu, Zn as indicated.
Labour	1100	Actual; Roughly 1 FTE/2 pivots
R&M variable	900	Actual
Depreciation	600	Vehicles and Mach. 10%; pivot infrastructure 5%
TOTAL	**5000**	
Cost/ha/day ($)	**13.70**	

Using this cost/ha/day and accurately putting against grazing days, cost of gain (CoG) could be more appropriately estimated. Example of estimates of unsupplemented cattle are provided (Table 4.6.2)

Table 4.6.2: Estimate of CoG for unsupplemented Wagyu cattle grazing irrigated Rhodes grass pastures.

Cattle	Average wt kg	Months	ADG kg/day	CoG $/kg	Comments
KB* m/s	**307**	**Dec-Feb**	**0.52**	**2.46**	High stocking rate
PB wnrs	**203**	**May**	**0.54**	**3.66**	Cooler – less pasture growth

Example: cost of gain calculation

On 17 Dec 2019 a mob of 875 Kimbara* (KB) m/s and pastoral cattle commenced grazing Pivot 14: amongst these was a core group of 675 KB cattle grazing continuously till a final weight date of 2 March 2020, a period of 76 days. (*Kimbara cattle were essentially a Wagyu/Santa Gertrudis cross)
Average ADG over the period was 0.52 kg/day for the core group.
Over the same period various other mobs of cattle of similar weight range were added and removed. With reference to a pivot grazing record (Fig. 4.6.1) the grazing days of the varying cattle numbers were recorded, referenced against the area grazed over that time.

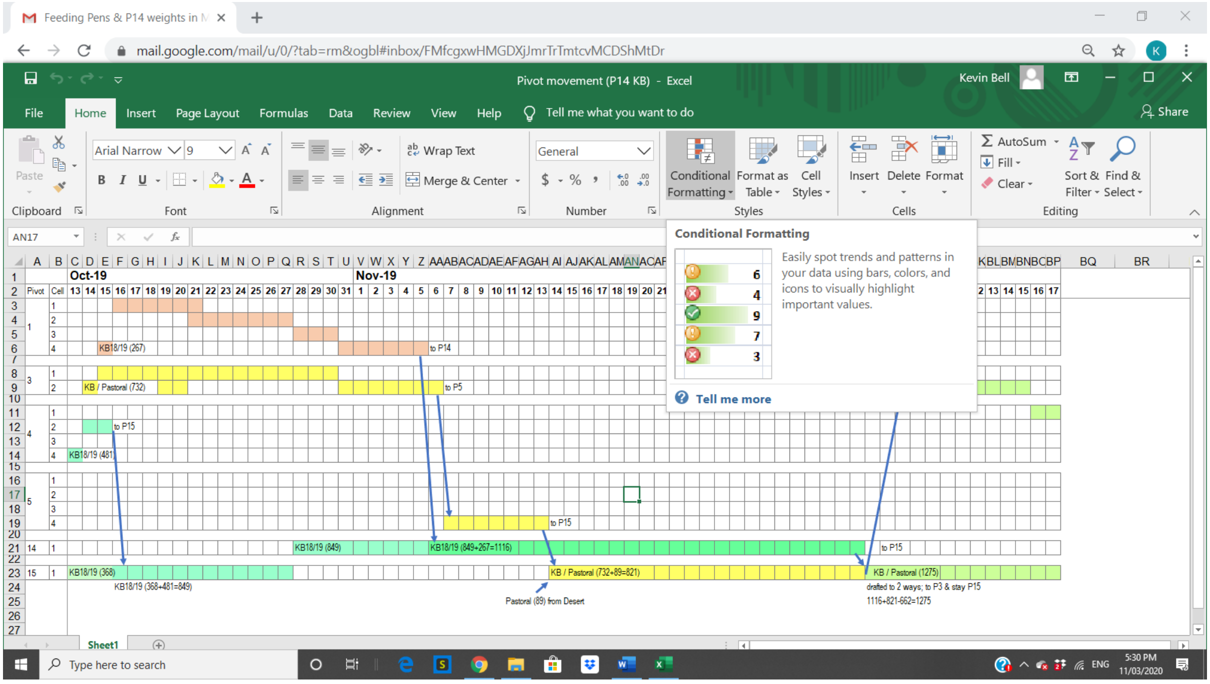

Figure 4.6.1: Sample daily grazing record of cattle number and location utilised in CoG estimates.

Included for costing were the days of regrowth up till grazing, from the date of prior grazing or resetting of the pivot areas used.

The average weight gain of the 675 core indicator group was applied to all cattle with reference to number, areas grazed and days grazing each paddock (Table 4.6.3). In this way the weight gain realised from the grazing time of each group of cattle could be applied to measure a total weight gain from the pasture areas grazed over the period, including pasture regrowth from last treatment to the start of grazing (Table 4.6.4).

A total of cattle grazing days/ha was calculated, and using the standard current pivot running cost of $13.70/ha/day a total cost could be derived.

Results

Figures used in calculations:

Pivot pasture cost $/ha/day:	$13.70 ($5000/year)
Cattle ADG	0.52 kg/head/day

Table 4.6.35: Cattle weight gain change and average daily gain.

Cattle number 675	Cattle average weight (kg)	Weight gain (kg)	ADG (kg/day)
18.12.2019	271.1		
3.3.2020	342.7	71.6	0.52

Table 4.6.4: Grazing record for calculation of CoP grazing.

Pivot/ cell	Area (ha)	Cattle number	Date in	Date out	Days	Grazing days	Gain(kg)	Grazing days
P14	50	875	18 Dec	5 Jan	19	16625	8645	950
P14	50	936	6 Jan	23 Jan	18	16848	8761	900
P3	40	936	24 Jan	3 Feb	10	9360	4867	400
P1 C1+4	20	936	4 Feb	9 Feb	6	5616	2920	120
P14	50	675	10 Feb	2 Mar	22	14850	7722	1100

Table 4.6.56: Pasture regrowth days prior to grazing for calculation of CoG grazing.

					Regrowth days
P14	50	13			650
P3	40	18			720
P1	20	14			280
P14	50	16			800
			TOTAL	**32915 kg**	**5920***

*Grazing and prior growth days contributing to weight gain

At $13.70/ha/day pivot production costs, total cost of hectare days was 5920*$13.70 **=$81104.**

Cost of gain/kg ($) 2.46

Discussion

Circumstances influencing this result were pasture growth rates, leaf quality and availability, and efficient utilisation through largely set stocking fortuitously aligned with pasture growth rate.

Pasture cost

Reference to the spreadsheet QuikIntake (McLennan and Poppi 2019) was used as guide to estimating pasture costs. This gave an indication of pasture intake, for the cattle involved (Fig. 4.6.2).

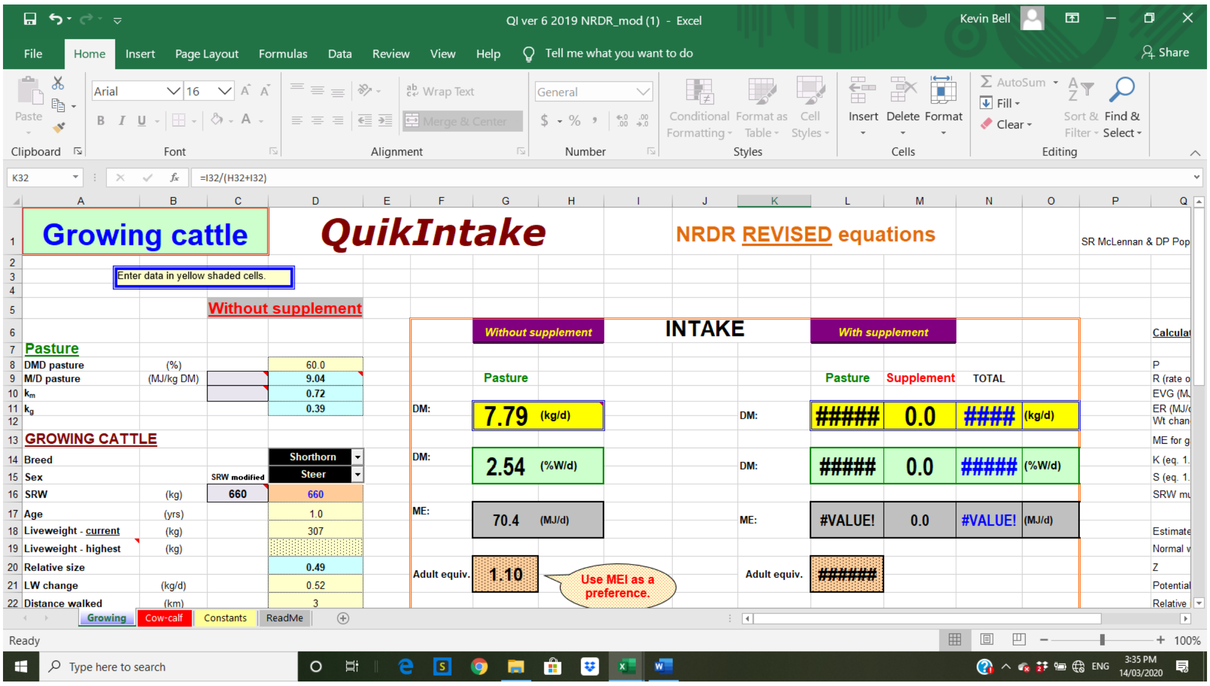

Figure 4.6.2: Example of Quikintake in estimation of grazing cattle intake.

Using a pasture leaf quality of 9 MJ ME, the weight and weight gain recorded and the breed composition of the cattle a cost of pasture eaten was estimated. The calculated consumption, for a "Shorthorn" breed, is 7.8 kg/day, close to the expected 2.5% Bwt. The consumption for a breed with 50% Bos indicus is given as 6.8 kg, or 2.2% Bwt. A Kimbara could be somewhere between, an estimated 7.3 kg/day.

Using this assumption, the cost of a kg of pasture eaten was easily calculated:
Daily consumption 7.3 kg pasture for 0.52kg weight gain.
Consumption to give 1 kg liveweight was therefore 14.0 kg pasture. Cost of pasture eaten could therefore be estimated with the calculation $2.46/14, or $0.18/kg. Estimation of pasture utilisation was always a vexing subject, but at 50% the figure for cost of pasture grown would be $0.09/kg. This was derived at a time of maximum growth rate; given the three-fold range in pasture growth rates estimated winter production would be more expensive.

In time, monthly costs might be estimated but accurate weight measurement of precisely grazed cattle during each month will firm up annual CoG calculations for cattle and pasture.

4.7 Production effects and cost of production for Wagyu cattle grazing irrigated tropical pastures with energy supplementation

Introduction

Experience to date indicated an intake limit for cattle grazing Rhodes grass. This had the effect of restricting weight gain to a degree that cost of gain was identified as potentially prohibitively high. In addition, the growth path for optimum Wagyu beef production was inadequate.

As understood, the limit was imposed by pasture digestibility and energy content. The place of an energy supplement with pastures such as available at Pardoo was considered on the basis on limited results reported from Australia (Moss and Murray 1992) where it was demonstrated that dairy weaners grazing irrigated tropical pastures in Queensland maintained liveweight gained above 0.6

kg/day with maize provided as an energy supplement. Without supplementation, calves gained only 0.2-0.4 kg/day, and the primary limitation to growth of these animals was intake of digestible energy. With grain supplementation, nitrogen retention and liveweight gains were increased, indicating that the extra intake of energy increased the efficiency of use of dietary protein obtained from pasture. Rhodes grass pasture was relatively high in protein with CP more than 17% and cattle digestibility 58 – 61%. Significant protein loss is expected in the case of a diet with 60% digestibility with dietary CP above 11% (Poppi and McLennan 1994), certainly often exceeded with Pardoo pastures.

Contact with South American research workers (D. Costa, personal communication) added to the hypothesis that an energy supplement would be of value in enhancing productivity of Wagyu cattle grazing irrigated tropical pastures.

Methods

Several energy supplements were used. Maize was considered but unavailable initially. High energy pellets (Maximise™, Milne feeds, 13 MJ ME)) and molasses were initial energy sources. Pellets were fed in feeders, molasses in tubs. Intake was monitored and some control attempted; in the case of molasses intake was encouraged by supplying as many tubs as possible and keeping molasses available.

Results

A summary of supplementary feeding evaluations is presented in Table 4.7.1

Pellet intake was relatively high in some circumstances but the results were remarkably in line with the hypothesised gains. Pasture intake in the case of supplemented groups was inferred by reference to the spreadsheet QuikIntake.

Table 4.7.1: Cattle weight gain grazing irrigated tropical pastures in association with energy supplementation.

	Cattle	Suppl't	Initial wt kg	Final wt kg	Wt gain kg	days	ADG kg/day	Suppl't intake (kg/head)	Cost of gain $/kg #
1	PB m/s weaners	pellets	196.8	253.6	56.8	86	0.67	2.8	3.15
2	KB heifers	molasses	236.0	282.3	46.3	52	0.89	0.5	1.60
3	KB m/s	pellets	169.0	205.9	36.5	54	0.68	1.9	2.59
4	KB m/s	Molasses	275.3	323.0	47.7	59	0.81	0.7	2.38
5	KB steers	molasses	335.0	364.9	29.9	48	0.62	1.9	3.54

CoP derived from either direct grazing costs plus supplement costs – see Section "Cost of production of beef on irrigated pastures", or by reference to Quikintake for pasture intake at a standard cost of $0.20/kg pasture eaten.

Detail for selected records gives an example of performance and cost derivation.

- Record 5 - Molasses supplementation March April 2020

In March and April 2020 a mixed mob of 547 cattle were set stocked on 50 ha for 48 days. Grazing management attempted to provide Feed on offer (FOO) at least 1000kg/ha for the period.

Molasses intake: 34450 L (50T), equivalent to 1.3 L (1.9 kg)/hd/day

Cattle weight change

Table 4.7.27: Cattle weight change grazing irrigated Rhodes grass pasture and supplemented with 1.5L/day molasses.

Cattle number: 547	Cattle average weight (kg)	Weight gain (kg)	ADG (kg/day)
3.3.20	335.0		
21.4.20	364.9	29.9	0.62

ADG for different cattle classes in the mob:		
	KB steers	0.63
	KB heifers	0.52
	Pastoral	0.72

Cost basis:

Pivot $13.70/ha/day
Molasses $500/T

Pivot pasture cost

50 ha x $13.70/ha/day x 48 days = $32880

Supplement cost

50 x 500 = $25000

Total costs: $57880

Weight gain: 547 x 0.62 x 48 = 16355 kg

Cost of gain: $3.54/kg

Discussion

It was interesting to note the variation in performance between KB steers and heifers (0.63 vs 0.52 kg/head/day respectively) and “pastoral” cattle – around 50% *Bos indicus* content (0.72 kg/head/day)

The cost was greater than would be expected with a planned energy supplement at this stage. The likely background to this was:

1. Pasture growth rate falling behind cattle requirement. It was clearly apparent over the last 3 weeks at least of the period that the pasture was increasingly being grazed to below the leaf layer and into the lower stemmy stratum. Cattle were noticed to be uprooting stem and selectively discarding portions. Diet quality and quantity clearly reduced with effect on intake and growth rate.
2. Excessive molasses intake to replace pasture – significant substitution, supplement intake higher than planned and cost therefore higher.

Lessons:

- Grazing management still the key – more leaf allowance, improved diet quality.
- This would come at the cost of running over a greater area, therefore cost increase.
- Supplement intake would be less, less cost
- The bottom line – probably still above $3.00/kg beef.

Reference to QuikIntake provided some background to this:

It is calculated that the cattle pasture intake would have been 7.6 kg/head/day of pasture plus 1.9 kg Molasses, at the higher edge of potential intake possible, 2.6% of Bwt. 83.8 MJ ME from such a diet would be associated with such a weight gain, no surprises.

The inevitable conclusion from this is that, in association with the estimated CoP, pasture costs remained low at this time of the year with pasture growth rates still high – calculated here as \$0.16/kg eaten or \$0.08/kg grown, at 50% utilisation.

Quikintake estimations of pasture intake including substitution where supplement intake was measured appeared to fit closely with likely cattle performance. Applying these predictions to the economics of supplementation indicated that with pasture costs as estimated in the warmer months (\$0.20/kg as eaten) the cost of gain was similar or slightly reduced. This of course depended on the cost of the energy supplement and the cost of supplying to the cattle. An example (Record 4, Table 4.7.1) with pasture at \$0.20/kg eaten and molasses at \$500/T delivered is provided (Table 4.7.3). In this calculation it is presumed that cattle intake of pasture is at a maximum, in this case 2.4% of average weight. If the cattle did not have access to the supplement and ate the same amount of pasture, gain was predicted to reduce to 0.62 kg/day. (This intake is considered relatively high for tropical pastures but is predicted in this case).

In winter with pasture costs at least relatively double, any economic advantage of supplements becomes increased, as is exemplified applying a pasture cost of \$0.40/kg eaten.

Table 4.7.3: Prediction of cost of gain using Quikintake and two costs of pasture eaten.

Cattle	ADG kg/day	Suppl't/day	Cost \$	Pasture intake kg	Cost \$	Feed cost/day \$	CoG Pasture \$0.20/kg	CoG Pasture \$0.40/kg
KB m/s steers	0.81	0.7 kg molasses	0.35	7.2	1.44	1.79	2.21	3.99
	0.62	-	-	7.2	1.44	1.44	2.32	4.65

The weight gain increases observed were similar in relativity to that in cattle supplemented with 0.6 – 0.9% LWt of an energy supplement grazing the tropical pasture *Brachiaria brizantha* in Brazil (Costa et al. 2019). Non-supplemented cattle gained 0.4kg/day compared with those supplemented, 0.8 kg/day). The results were achieved with less supplement than in the current trial, associated with better pasture digestibility and availability.

From the weight records obtained it could be concluded that energy supplementation did increase cattle weight gain beyond that expected on tropical pastures. Depending on the estimated cost of pasture, the cost of gain was similar or modestly reduced.

Molasses was favoured over grain or pellet energy sources mainly on account of ease of provision in a restricted manner and economy of infrastructure. Refining the provision of supplements to grazing cattle, molasses, grains and silage, remained an ongoing priority.

Optimum grazing management to enable maximum leaf intake would remain the major influence on cost of cattle weight gain; where an increase in rate of gain is indicated by preferred growth path then an energy supplement is effective.

4.8 Satellite imagery to estimate pivot pasture biomass as an aid to grazing management

Background

With the acknowledged importance of optimum grazing management for pasture and cattle performance, the purported level of accuracy of remote sensing via satellite was explored for irrigated Rhodes grass in the context the Pardoo Wagyu program. This was completed in cooperation with Murdoch University as part of an Animal Science honours project.

Methods

Quadrat cuts (n=165) were sampled over 33 sites across 17 pivots (Fig. 4.8.1) from April to July 2019. Sites were selected for variation to sample the largest range of pasture stages and biomass. Biomass means were then compared to reflectance readings for those 33 sites for each band available. A rising plate meter was also evaluated independently using quadrat cuts. Results were supplied to Cibo labs.

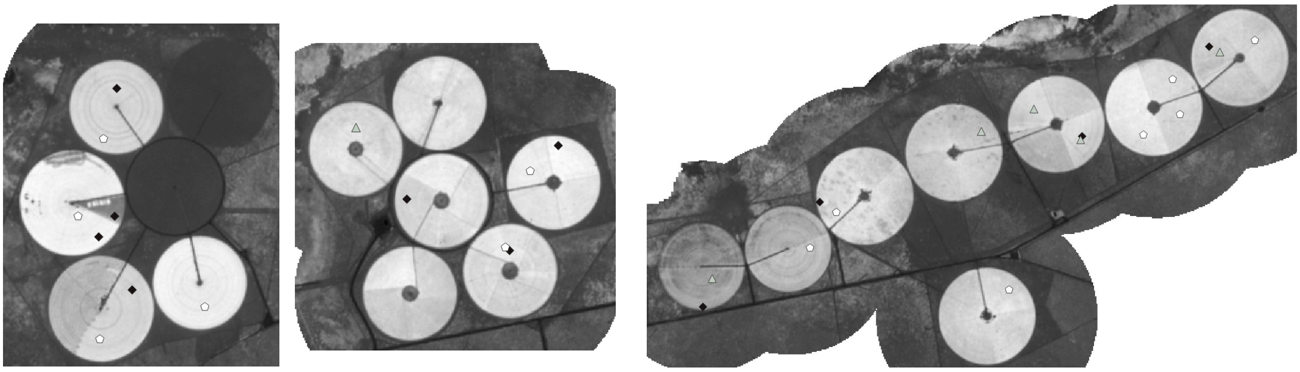

Figure 4.8.1: Pardoo pivots: stages one, two and three. 165 quadrat cuts were taken from 33 sites over a four-month period.

Results

Of the tools available in this study, the Sentinel 2 MSI 13 band imagery reflectance had the strongest relationship observed with R^2 = 0.94 between the 13 bands reflectance values and pasture biomass with a significance of P = 0.001. A predictive model was formulated from the strong regression of Sentinel 2 in the construction of a tool in the estimation of Rhodes grass biomass to increase efficiency of grazing management (Table 4.8.1).

Table 4.8.18: Relationship values for four tools tested against biomass (kg/DM/ha), p-values for each relationship explored. Satellite scores based on quadrant cuts (n=33)> RPM scores based on quadrant cuts (n=19).

TOOL	Regression	p-value	Correlation	p-value
MSI (13 bands)	0.94	0.0000		
7 bands	0.61	0.0006		
NDVI	0.16	0.0201	0.40	0.01968
RPM*	0.89	0.0000	0.94	0.00128

Of significant value also was the demonstration of a strong linear relationship (P<0.0001) between pasture height obtained by rising plate meter* (RPM) and biomass (kg/DM/ha) with an R^2=0.8868 (Fig. 4.8.2).

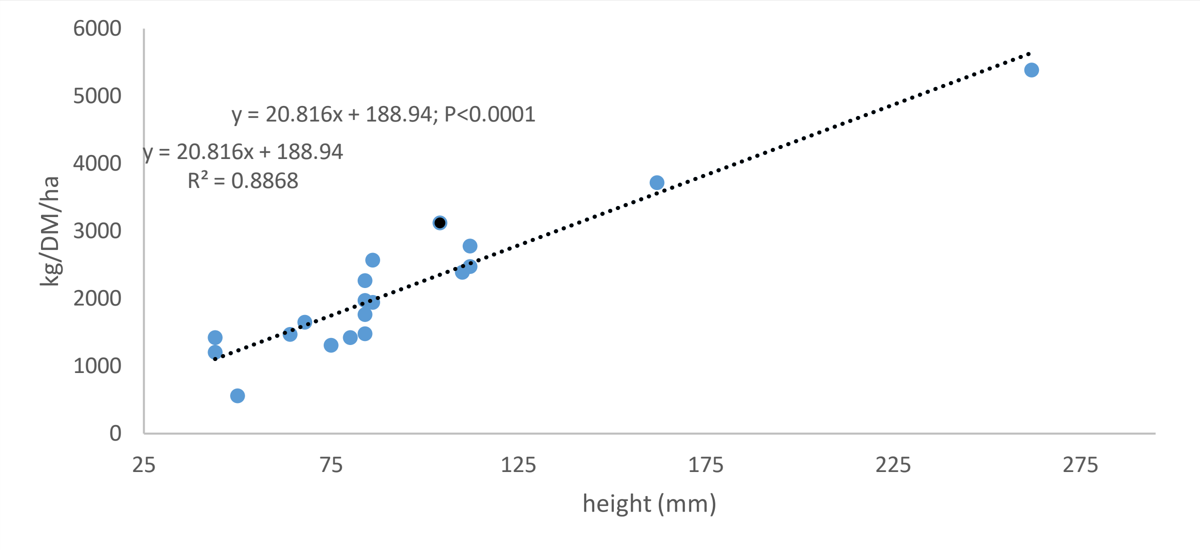

Figure 4.8.25: Relationship between average biomass and pasture height using the Rising Plate Meter (n=19).

Discussion

NDVI has long been the predominate method of remote sensing, both in satellite imagery, handheld sensors and unmanned aircraft. However, in this study on a tropical grass, NDVI yielded a very weak regression (Figure 4.8.3), markedly lower than seen in other studies as on annual pastures (Edirisinghe, Hill, Donald & Hyder (2011) who observed a relationship of R^2 = 0.82 between biomass and NDVI reflectance of southern western Australian pastures with the use of Landsat 5 in 1995-98.

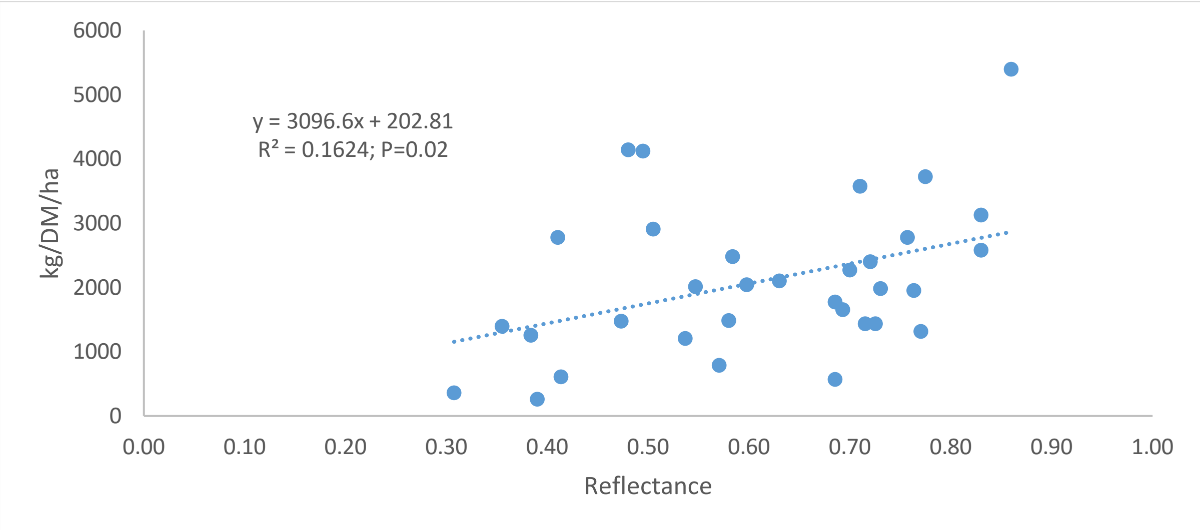

Figure 4.8.36: Regression between NDVI reflectance and biomass (kg/DM/ha) using the combined data from 3 collection dates and 33 cut sites.

The use of these results by grazing managers is being evaluated in practice as aids to grazing management.

4.9 Feedlot evaluation

Reference to local and international data would indicate that in the Pardoo environment maize silage production was associated with highly efficient use of resources (water, nutrients) and the cheapest high quality forage energy source for cattle feed.

Maize for silage production was planned for winter of 2018, but due to land clearing delays planting was delayed and a crop of reduced yield but high quality was harvested and ensiled in January 2019. Based on this feed source a least-cost ration was formulated with the guidance of a feedlot nutrition consultant (Table 4.9.1) and used to background cattle before their transport to a southern feedlot for finishing.

Table 4.9.1: Pardoo least cost grower ration cost and components.

Component	DM %	ME	CP	% of ration As fed	Cost as fed $	Ration contribution ME MJ/kg	Ration contribution CP%
Maize silage	35	10.5	7.5	70	61.25	4.9	3.5
Lupins/min vit	90	14.0	30.0	8	73.60	2.2	4.5
Wheat dry rolled	90	12.0	12.0	22	125.40	4.6	4.6
TOTAL RATION DM 51%					**260.25**	**11.6**	**13.3**

Results

Observations and analysis of management data recorded over the period August 2019 to April 2020 enabled some evaluation of rations and the performance of a variety of Wagyu and Wagyu cross cattle in the Pilbara environment (Table 4.9.3).

Selected weather data from the DPIRD Pardoo weather station are included (Table 4.9.2).

Table 4.9.2: Selected weather data from Pardoo DPIRD weather station August 2019-May 2020.

Month	Min temp °C	Max temp °C	Avg temp °C	Avg RH %	Rain mm	Wind AvgSpeed @3m	Avg soil temp °C	Solar exposure MJ
May-20	13.3	37.8	23.6	40.6	35.2	11	28.5	547.3
Apr-20	19.2	43.1	29.7	59.4	7.4	8	36.1	634.1
Mar-20	21.9	44.2	31.4	66.2	8.6	8	38.6	787.2
Feb-20	22.7	44.1	30.8	68.3	5	11	37.8	764.8
Jan-20	23.0	42.1	30.5	73.2	142.8	12	36.0	776.5
Dec-19	19.2	46.9	32.3	57.2	7.4	11	39.4	838.1
Nov-19	15.8	44.4	31.2	51	0	10	38.0	918.0
Oct-19	16.1	44.7	29.7	57.3	1.4	9	36.4	884.4
Sep-19	9.1	41.9	24.4	53.3	1.8	9	30.2	808.3
Aug-19	10.3	37.8	23.2	39.8	0.6	12	26.8	758.2

Table 4.9.3: Background feeding performance of range of Wagyu-derived cattle at Pardoo August 2019-April 2020.

Cattle	ADG (range) kg/day	FCR (range)	Cost of gain ($)
PB steers	0.84 (0.59-1.58)	8.1 (6.4-8.4)	3.91 (3.08-4.81)
KB steers	0.67 (0.51-0.79)		
KB steers	0.79	10.0	4.81
KB heifers	0.67 (0.29-0.98)		
KB heifers	0.90	7.2	3.48 (3.08-3.87)
KB m/s	0.75 (0.42-1.19)		
KB m/s	0.57 (0.46-0.67)	14.1 (11.9-16.3)	6.81 (5.75-7.86)

The period encompassed the hotter and more humid summer months, which was recognised. Shade had been planned but installation was delayed until after these measurements were recorded and any comparisons not possible. A reduction in cattle performance was observed (Table 4.9.4), although cattle groups were not necessarily comparable.

Table 4.9.4: Effect of season on Wagyu and Wagyu cross cattle performance in the Pilbara.

Period	ADG kg/day	FCR feed: beef	Cost/kg gain
August- Dec	0.84	7.8	$3.75
Jan - April	0.76	10.4	$5.03

Discussion

Most of the records relate to period of high heat load for cattle, from December to March. This would contribute to the disappointing FCR and CoG. The slower growth rate programmed through unavoidably contributed to these results.

Grouping of mixtures of cattle class was responsible for the paucity of FCR and CoP for KB class cattle. Weight gain was able to be calculated but not intake.

The formulated ration would be expected to give a weight gain of approximately 1.0 kg/day in, for example, a 300kg Brahman cross animal, at a cost of $3.00 - $3.50/kg gain. The Wagyu-derived cattle over the period August to October 2019 demonstrated that this degree of performance was achievable, but with the aim being backgrounding for subsequent finishing in a southern feedlot, a lesser amount of ration was provided with consequent slower gain and unavoidable higher costs. This was the case observed for most cattle groups fed for which records were available.

Performance over the summer months was encouragingly good, particularly in the absence of shade. This was very likely associated with the grower ration and limit feeding to manage a slower weight gain with a slower growth path and less metabolic heat load, given that the main source of body heat accumulation in cattle is metabolic heat. Also, heavier cattle are more susceptible to heat load. The performance was therefore not comparable with that of feedlots in general with more efficient and cost-effective finishing rations with higher rates of gain.

There were only isolated signs of heat-induced discomfort as indicated by a small proportion of cattle observed with panting scores of 2.0 or greater. These signs were not evident until January; the cattle displayed no signs of excessive heat load before then, even with relatively high maximum daily temperatures. Factors associated with any symptoms of EHL were increased overnight minimum temperatures and increased relative humidity, recorded over the January to March period.

Katestone Environmental prepared a Heat Load Analysis for Pardoo, using the Pardoo pivot site DPIRD weather station data from September 2017 to April 2019. While the predicted heat load for the cattle would relate to a feedlot environment it did relate to the behavioural observations made. Predictions were that Wagyu cattle in the 2018/2019 summer would not have been able to sustain high growth rates as for finishing cattle.

In summary, these data can be applied to selected feeding systems as applied in the environment experienced. A purpose-designed and built large scale feedlot incorporating shade would be expected to be associated with better cattle performance and lower cost of gain. However, this was not evaluated.

Imported ration ingredient costs were inevitably more expensive in the Pilbara associated with freight; an amount of approximately $150/T applies to most materials and must be factored in ration formulation and in management decisions related to location of ultimate finishing and slaughter.

4.10 Gastro-intestinal parasite management

With cattle grazing at relatively high stocking rates for much of the year, there was the potential for serious parasitism (for example, recorded annual average stocking rate was approximately 8 AE/ha, ranging from 13 AE/ha in summer to 4 AE in winter).

The environment of high temperatures and green pastures was clearly conducive to larval survival and transmission to grazing cattle.

The opportunity was taken to monitor aspects of parasitism which might influence cattle performance in the Pardoo environment.

Observations on parasite ecology

In June 2018 a worm egg count (WEC) was performed on a group of 400 young Wagyu purebred cattle weaned at approximately 6 months of age in January 2018. At weaning they had been treated with the anthelmintic Dectomax™ pour-on. They appeared in good health and were gaining weight. They had been grazing irrigated Rhodes grass pastures in a rotational program over the period. The WEC average of 603 eggs per gram (epg) with a range of 0 – 1900 epg of 12 individual samples could be considered relatively high, but significance would depend on the species of worm involved.

Larval differentiation was obtained from DPIRD Parasitology laboratory, indicating the species present (Table 4.10.1)

Table 4.10.1: Gastrointestinal parasite larval differentiation Pardoo June 2018.

Species	Ostertagia	Trichostrongylus	Haemonchus	Oesophagostomum	Cooperia sp.
	%	%	%	%	%
	0	0	75	8	17

The WEC was not excessive considering the prolific egg-laying of Haemonchus, the predominant species at the time. However, the potential for sudden high levels of larval acquisition and acute parasitism was recognised. The decision was made to monitor WEC of the cattle monthly, whilst monitoring health and performance.

Table 4.10.2: Sequential WEC for untreated weaner Wagyu cattle 12-24 months of age grazing irrigated tropical pasture.

Date	WEC average	WEC range	WEC positive (number/12 samples)
01.06.18	603	0 - 1900	11
12.07.18	693	150 - 1620	12
07.08.18	115	0 - 420	9
11.09.18	135	0 - 840	8
28.11.18	35	0 - 150	6
04.02.2019	40	0 - 240	5
28.03.2019	70	0 - 360	6
30.05.2019	233	0 - 660	11

The results (Table 4.10.2) were instructive in that within 2 months the WEC dropped abruptly and remained low through the following summer, until in May 2019 at about 2 years of age WEC increased significantly. Cattle were still gaining weight. At that time, possibly for the first time the available pasture had become lower in height (to 5 cm) and biomass and the opportunity for larval acquisition much greater.

The cattle were treated again with the same anthelmintic, and the opportunity taken to gain some indication of possible parasite resistance to the active ingredient doramectin. This compound is widely used in the northwest cattle industry on account of its novelty and convenience of application, injectable or pour-on.

A field faecal egg count reduction test (FECRT) was conducted, the results (Appendix 9.2) indicating either developing resistance and/or careless application – the latter certainly very likely. WEC reduction of 80% was recorded.

With a random 12 cattle sampled at each date, FECRT accuracy would be less, and approximate only; however experience was that such a test remained a reliable indicator.

Dectomax™ pour-on should have 95% or better egg count reduction for roughly 5 weeks. The post-treatment WEC in this case was 25 days after treatment.

Recommendation was made to follow application instructions carefully, and to re-dose any cattle where less than proper application was suspected.

Comments

At first consideration, the apparent minor impact of worms on young growing cattle in the seemingly dangerous environment was surprising, but in fact the pasture grazing management and environment were not necessarily conducive to larval acquisition.

- Residual pasture height was often 15 cm and higher.
- Pasture bulk density was low.
- Utilisation (proportion of pasture on offer eaten) was routinely low, as is typically the case with tropical pastures. Although difficult to precisely quantify utilisation was often estimated as below 40%.
- The avoidance of excreta-affected pasture areas was very strong and extended to more than twice the area of the faecal deposit.
- Cattle tended to camp on bare ground adjacent to the pasture, and a significant proportion of dung was deposited there rather than on the grazed pasture.

- Even if pastures were reset by mowing and removal of excreta-affected and rejected pasture, the patch grazing often persisted into the next grazing session – i.e. larval contamination of pasture eaten could remained relatively low.
- High soil and ambient temperatures for much of the year may not favour larval survival. Specific investigations of this and the other factors referred to would be necessary to quantify if the issue became serious.

Despite this parasitism should always be recognised as a potentially serious problem in specific circumstances, understandably should pastures become low in the areas between dung patches and cattle forced to eat closer to dung patches.

5 Discussion

In light of the early-stage of this project, the majority of the objectives were aligned with the feed production base, primarily the irrigated tropical grass pastures and fodder crops. Some projected objectives anticipated (marketing and market access, supply chain innovation with associated areas of eating quality and chain assurance, as examples) understandably did not progress within the 3 years of this project. With the innovative and pioneering nature of the agricultural venture came research concerned with the associated water and soil. The relative isolation and large scale of the project introduced additional complexities of staff skills and interactions, as communication had to be fostered and maintained between the inevitably areas of specialty (for example, pivot and irrigation, machinery operations, grazing management, cattle management, feedlot operation, rangeland management, land development including infrastructure).

The role of the Technical innovations Manager was to evaluate the issues present and arising over time, and bring science and objectivity to achieve the core business plan, bearing in mind operational efficiency, environmental sustainability, the effect of the feed base on the whole supply chain and eventual market requirements. The more significant of these issues, and those for which meaningful insights were forthcoming, comprise the contents of this report.

In fact, it became apparent that some areas having a major influence on productivity would require some degree of basic and applied research. If this was to be accomplished, it must take place within the day to day activities of the commercial operation – this was not a research institution! Results presented and discussed in this report came from this environment. However, to strive for rigor of data collection was maintained as a priority throughout. It was inevitable in these circumstances that much data collected would fall short of being subject to meaningful analysis; this was recognised, accepted and we moved on. Despite all this, the project did provide robust and meaningful guidance to the development of the business.

The successful production of Rhodes grass hay over some time in the Pilbara and adjacent Kimberley had given some confidence to the plan to use this grass managed under direct grazing as a feed source for beef production. Impressive hay yields in the vicinity of 40 tonnes per hectare of dry matter had been reported. Grazing of a single pivot at Mowanjum near Derby had been promoted as a component of a “Water for Food” Project and some guidelines for grazing arose from that source. These were quite in line with conventional rotational grazing principles. As the Pardoo project progressed and pivot numbers and areas increased, the difficulties associated with matching grass production to grazing cattle numbers became evident. This is discussed in detail in this report. The issues involved were not fully resolved, although scale and logistics did play a part. Grass utilisation is a key component of a profitable and sustainable grazing system, and as observed Rhodes grass pastures in this environment did not consistently perform as expected even with perceived good grazing management in line with grazing guidelines.

Any aids to facilitate estimates of pasture biomass and growth rates were evaluated, in addition to the recommended visual calibrations employed in the grazing guidelines. The use of satellite imagery would be an adjunct and use in practice had commenced; initial consideration was that it was of value for uniform leafy crops or pastures. Further use and field calibrations were continuing. The rising plate meter also mirrored this relationship.

Certainly, the cost of cattle bodyweight gain on the pastures has been difficult to address; it was still being calculated as more than $3.00/kg. The two most recent and robust estimates were $2.46/kg for KB cattle over the December to February summer period and $3.66/kg for PB cattle in May. Cost was estimated to increase over the cooler months with less response to fertiliser. As an observation the CoG for purebred Wagyu cattle was higher than for those with some *Bos indicus* content. Addition of an energy supplement to the pasture diet did show some modest reduction in CoG together with increase in growth rate, ($1.60 to $3.54, averaging $2.65/kg; cost increased in cooler months as for unsupplemented cattle). Although these CoG costs under grazing were higher than desirable, they were still lower than those in a feedlot or “cut and carry” system. The full evaluation of the two feeding systems in the Pardoo environment has not yet been established; that they were complementary did become clear, in that a tropical pasture with direct grazing as a significant component of utilisation cannot be managed without recourse to mechanical conservation, ideally in a state with optimum quality for livestock nutrition to contribute to the feedbase.

With regard to farm gate cost of beef production, the contribution of the weaner calf component was not evaluated; this will be calculated as a cycle of rangeland breeder management to calf weaning is completed. Acknowledging the lower cost of weaner production from rangeland calving, farm gate cost of production for 350 kg cattle may be as low as $2.50/kg, reproductive rate and calf weaning weight being the important variables in the rangeland production system. The opportunity to objectively evaluate the entire system has not been available to date but will soon eventuate.

The quality of the Rhodes grass pasture remained a factor in CoG, as digestibility of leaf seldom was greater than 60% with ME values of 8.5 to 9.0 as a limit. Any grazing outside the guidelines of leaf availability would be associated with lower intake including some stem, further reducing digestibility. It was not possible to measure intake with any precision, but 2.2% of bodyweight was a figure supported in the literature, and highly likely a useful figure with which to work. It did fit in many instances with measured performance in association with pasture digestibility, cattle weight, and gain. The increased use of fertiliser nitrogen, as indicated by the major nutrient response trial, had minimal effect on pasture nutritional attributes; high levels of N application in cooler months did produce higher plant protein levels, without discernible effect on digestibility. In general winter pasture quality was better than that in summer.

The soil pivot environment remained excellent as far as could be measured; irrigation was improved and maintained soil water levels in an ideal state, with water confined to the top 1500mm. Nutrient loss was considered minimal. Healthy plant root systems were observed to this depth and beyond, with the capacity to supply required nutrients to pastures. Especially pleasing was the maintenance of soil pH under what would typically be soil acidifying circumstances. The alkaline features of the water would be considered responsible for this, certainly a benefit. In addition, the water contained the plant-required nutrients potassium, magnesium and sulphur, with considerable cost saving in the case of fertiliser.

In irrigated fodder production systems, the water source analysis was clearly of significance, and should be taken into consideration in each case with regard to forage nutrient supply and balance, and cattle diet. For the Wallal aquifer the notable attributes were high sulphur and moderate potassium levels, and alkalinity. All were beneficial for plant nutrition and soil health. Amelioration of cattle diet in recognition of the high sulphur levels was required and easily managed.

In tropical fodder production local environments commonly differ, and with the high production potential nutrient response trials in each are recommended. Returns to correct fertiliser use are high, as was the case for Pardoo.

Initial maize and sorghum crops demonstrated the place of forage crops as locally grown fodder and were conserved as high-quality silage. This was the basis for least-cost grower rations used in pilot feeding studies. Cattle performed as expected; a slower growth rate programmed by diet unavoidably contributed to the performance, not comparable with finishing performance. Most of the records related to periods of high heat load for cattle, from December to March. This was a factor in the disappointing FCR and CoG. Overall CoG ranged from $3.08 to 7.86/kg, with performance in the cooler months ($3.75/kg) better than that over the January to April months ($5.03/kg). With the relatively modest growth rate programmed, heat load did not become an issue; it would be expected that a finishing feeding program would induce heat loads difficult to manage. This was not evaluated.

In summary, conventional feedlot performance and profitability was not evaluated, but it would be expected that satisfactory performance would occur over the cooler and less humid months April to December. The humidity and warmer night temperatures over the remaining summer months (Table 4.9.2) would not permit full feeding, and even with the low energy ration provided a small proportion of cattle displayed an increase in panting score.

The inability to acquire shade in time limited full evaluation of cattle performance with conventional feedlot infrastructure in the Pilbara environment.

The indication that forage crops (maize, sorghum) of feed quality superior to Rhodes grass, with better resource (water, nitrogen) use efficiency could be produced in the irrigated tropical environment was reason to pursue research on crop varieties and rotations. In a temperate environment Garcia et al. (2008) measured dry matter production, nutritive value and efficiency of nutrient utilization of a complementary forage rotation (CFR) compared to a grass pasture system. This study evaluated an annual sequence of three crops, (maize, forage rape and a legume), with a pasture (kikuyu grass over-sown with short-rotation ryegrass) as a pasture control treatment. Annual DM over the 3 years averaged >42 t/ha/yr for the CFR treatment and >17 t ha)/ for the pasture treatment. The high DM yield of the CFR treatment resulted from >27 t DM/ha/yr from maize harvested for silage and >15 t DM/ha/yr utilized by grazing the forage rape and legumes. Total input of nitrogen and water were similar for both treatments, resulting in higher nitrogen and water-use efficiency for the CFR treatment, which was more than twice that for the pasture treatment. This would seem to have high relevance to the Pardoo forage production program.

Some general comments:

Feed analysis is of extra relevance and importance when a component of a novel venture animal production venture. Consistent differences between feed testing laboratories were recorded over the project period. It is recommended that the same testing source be utilised when testing forages, and that comparisons between results reported from different testing houses be guarded. The possibility may exist that robust NIR calibrations for tropical grasses may not have sufficient consistency across providers to enable comparisons.

A whole of business recording program was not established over the project. A number of commercial agricultural systems were evaluated, but the requirements of a paddock to plate specialty beef system originating from a pioneering program in a challenging and remote environment were substantial and complex; it is a work in progress as the definitive requirements arise.

As an observation, the management structure optimum for an agricultural business of this scale in a remote and challenging environment had not been resolved and remained as an impediment to project progress. Limited and imperfect communication between managers of defined specialty areas laid a basis for imperfect relationships not conducive to the rapid responses required in managing tropical forage systems.

It is pertinent to reflect on unanswered issues and areas for which research may be warranted; bearing in mind that in north-western Australia, at least currently, there is a limited irrigated tropical pasture base. For the systems and coastal Pilbara environment under consideration, however, the following areas certainly have been identified as requiring evaluation with respect to their impact on pasture and cattle production. To varying degrees, they have unresolved significant potential to influence productivity and profitability in these systems.

1. The deployment of portable electric fencing to enable programmed pasture management of tropical pastures under centre pivot irrigation.
2. In view of the major contribution and expense of nitrogen fertiliser to irrigated tropical pasture production, the extent of nitrogen loss through volatilisation.
3. The impacts of diseases and pests on intensively managed irrigated tropical pastures is unclear; yellow-winged locust plagues are expected and prepared for, but several potentially pasture limiting diseases, likely fungal in origin, require definition.
4. The performance of alternative pasture species in comparison with Rhodes grass; this is one of few species permitted by statutory regulation in the region, and was clearly a most inferior grass with regard to cattle nutrition, in comparison with alternatives grown elsewhere nationally and internationally; it placed pasture-based cattle production from irrigated tropical pasture at a significant disadvantage on a global stage.
5. Energy supplementation to cattle grazing tropical pastures was shown to increase rate of gain, with some beneficial effect on cost of gain; comparing supplements available together with methods of provision was unresolved.
6. Given the documented performance of some forage crops, it would seem urgent to trial crop combinations and rotations superior for cattle nutrition and resource utilisation efficiency (Garcia et al. 2008).
7. The management of gastrointestinal parasites of cattle grazing intensively managed irrigated tropical pastures in the environment should be defined. Although managed over the term of this project, the potential for major acute disease and chronic loss of production should be recognised and guidelines established.
8. Conventional feedlot performance of cattle, in this case Wagyu, was not fully evaluated. Although a simulated feedlot environment was utilised, initial observations indicated that performance and cost of gain would not have been competitive within the Australian feedlot industry. However, the major resource use efficiency very likely associated with forage crop rotations would dictate development of confined feeding systems in the environment.

6 Conclusions/Recommendations

6.1 Future R&D

The unanswered issues identified as of relevance and significance over the course of the project have been discussed; certainly, the most important of these to pursue include:

1. In view of the major contribution and expense of nitrogen fertiliser to irrigated tropical pasture production, the extent of nitrogen loss through volatilisation.
2. The performance of alternative pasture species in comparison with Rhodes grass; this is one of few species permitted by statutory regulation in the region, and was clearly a most inferior grass with regard to cattle nutrition, in comparison with alternatives grown elsewhere nationally and internationally.
3. Energy supplementation to cattle grazing tropical pastures was shown to increase rate of gain, with some beneficial effect on cost of gain; comparing supplements available together with methods of provision was unresolved.
4. Given the documented performance of some forage crops, it would seem urgent to trial crop combinations and rotations superior for cattle nutrition and resource utilisation efficiency (Garcia et al. 2008).
5. To utilise the forages of complementary crop rotations, rations and efficient cattle feeding systems require evaluation.

6.2 Industry implications

This project has outlined cost of production under a range of systems and identified cost and production components. In doing a foundation exists to improve productivity of such a system in this and other environments, and is being actively pursued. It remains a worthwhile goal, although at present is likely to remain as a relatively minor contributor to the overall northern feed base.

If water availability increases throughout the northern beef production areas, interest in irrigated fodder may well increase. Thorough evaluation under each environment can be better made using data gathered and methodologies evolved during this project.

In closing, whilst PBC provides key baseline data and a real-life case study of practice change, importantly this report also provides to wider industry the value for allocating resources to the design and delivering of an innovation strategy that aligns to a clear business strategy. It is this capability building that remains an area MLA has identified requires further support to industry as an enabler to driving practice change and R&D extension.

7 Key Messages

Irrigated tropical pastures in the Pilbara environment are identified as a relatively expensive feed source for beef cattle. Utilisation by direct grazing whilst attractive conceptually and manageable in practice remains an economic challenge. Depending on location the advantage of annual feed availability of predictable quality may give confidence to target higher value markets.

Grazing management remains the key component to optimum productivity under this system.

This project has developed baseline methodologies to better calculate cost of production and identified key cost areas and production components. This has laid a basis on which to better improve efficiencies. This would be applicable across diverse production environments.

Underground aquifers present very minimal environmental disturbance with monitored water and fertiliser use.

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9 Appendices

9.1 Feed test report maize and sorghum silages

Table 9.1 Feed analysis Maize and sorghum silages ensiled January 2019.

Attribute	Maize Silage	Sorghum Silage
Dry Matter (DM, % as received)	97.7	91.7
Crude Protein (CP, %)	7.7	6.0
Acid Detergent Fibre (ADF, %)	25.3	36.4
Neutral Detergent Fibre (NDF, %)	44.4	61.4
Water Soluble Carbohydrates (WSC, %)	15.3	8.1
Digestible Dry Matter (DDM, %)	70.4	58.1
Metabolisable Energy (ME, MJ/Kg)	10.6	8.9
Phosphorus (P, g/Kg)	2.2	1.3
Potassium (K, g/Kg)	11.6	12.0
Sulphur (S, g/Kg)	1.5	1.1
Sodium (Na, g/Kg)	1.2	1.6
Calcium (Ca, g/Kg)	1.7	2.6
Magnesium (Mg, g/Kg)	1.3	2.5
Chloride (Cl, g/Kg)	6.7	10.1
Copper (Cu, mg/Kg)	7	6
Zinc (Zn, mg/Kg)	20	16
Manganese (Mn, mg/Kg)	36	41
Iron (Fe, mg/Kg)	3,585	707
Boron (B, mg/Kg)	16	9
Nitrate-Nitrogen (NO3-N, mg/Kg)	Under 40	116

9.2 Doramectin field use Faecal egg count reduction test May 2019

There is a reasonable amount of near-formed grain in the sample of Maize silage that will have contributed to reduce the ADF and NDF fibre attributes and to raise the DDM and ME values to these quite respectable levels. The CP is also quite good for a Maize silage and the residual WSC is at a fairly high level for this type of silage. This may indicate that there was only limited fermentation of the WSC during the ensilage process. The CP of the Sorghum silage is fairly low possibly reflecting the limited amount of leaf and the fairly high proportion of stem material in the sample. This stem material will have contributed to the quite high ADF and NDF values and these will have impacted to lower the DDM and ME values to these fairly modest levels. The residual WSC value is fairly low for a Sorghum silage and at this level would have had limited influence to enhance the DDM and ME values.

The Phosphorus in the Maize silage is at a level that could support a reasonable level of production while the level in the Sorghum silage is fairly modest. Calcium is down in the Maize silage and the ratio of precisely 2:1 - albeit with the Phosphorus down. The levels of Calcium and Phosphorus in the Maize silage are most likely influenced by the fair amount of near-formed grain in this silage. Potassium is at a reasonable level in both samples and more than adequate for most classes of cattle. Sulphur is at a level Ok for cattle in the Maize silage, but is fairly low as to be expected for the Sorghum silage. The level of sodium in both silages is not very high, but should be adequate for most classes of cattle. Magnesium in the Maize silage is adequate for maintenance of mature cattle while the level in the Sorghum silage is high enough to support good rates of growth. The Chloride in both silages is well above the levels required by all cattle, especially the level in the Sorghum silage. The level of Copper in both silages is probably marginal for some cattle while the levels of Zinc are within the range required by cattle. The Iron in the Maize silage is extremely high and probably reflects some soil contamination and the level in the Sorghum silage is also high. The levels of Nitrate-Nitrogen are not very high as may be expected, especially for the Sorghum silage with its low CP content.

Please Note: Due care and attention is taken in providing these professional comments, but no responsibility is accepted for any inappropriate action taken in response to these comments.

Doramectin field use Faecal egg count reduction test May 2019

Table 9.2: Field FECRT Doramectin pour-on efficacy Pardoo June 2019

		Worm Egg Count (WEC) eggs per gram	
	Date	31.05.19	25.06.19
		Pre- treatment	Post-treatment
	WEC	510	0
		0	120
		270	0
		360	120
		240	0
		90	0
		270	150
		30	0
		300	0
		30	90
		30	90
		660	0
AVERAGE		**233**	**48**
WEC positive		**11/12**	**5/12**
WEC % reduction			**80%**