



NORTHERN AGRICULTURAL REGION

LITERATURE REVIEW

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SECTION 1: BACKGROUND OF THE TARGET AREA: NORTHERN AGRICULTURAL REGION (NAR)

1.1 NORTHERN AGRICULTURAL REGION

The Northern Agricultural Region (NAR) of Western Australia (WA) is a rich farming and fishing area to the north and north east of Perth, covering 7.5 million hectares. It is characterised by pristine beaches and offshore islands, coastal sandplain with considerable areas of retained natural vegetation, and a fertile low-rainfall hinterland (Anon, 2004). The NAR is under the administration of 17 local government authorities including Victoria Plains, Gingin, Moora, Dandaragan, Coorow, Carnamah, Three Springs, Dalwallinu, Perenjori, Mingenew, Irwin, Greenough, Morawa, Mullewa, Chapman Valley, Northampton and Geraldton.

1.1.1 Regions

The NAR is divided into four (4) sub-regions, based loosely on natural catchment boundaries Figure 1. Yarra Yarra Catchment is the internally drained area between Kalannie in the south, Yarra Yarra lakes near Three Springs and extending north into the Morawa shire (Anon, 2004). Moore River Catchment lies between the river mouth at Guilderton inland to the Yarra Yarra lakes in the North East (Anon, 2004). West Midlands Catchment is the coastal area between Lancelin in the south and the Arrowsmith catchment in the north, extending east over the Brand Highway to include the Dandaragan township (Anon, 2004). The Hill and Arrowsmith Rivers are the prominent watercourses and there are several near shore islands. Greenough Catchment is the northern part of the region and includes catchments of the Irwin, Greenough, Chapman, Bowes and Hutt Rivers (Anon, 2004).



Figure 1: Sub-catchment and shires of the Northern Agricultural Region.

1.1.2 Geology and soils

Within the NAR there are four distinct geological provinces:

The Yilgarn Craton lies to the east of the Darling Fault and encompasses areas of the Yarra Yarra, Moore River and Greenough sub-regions. It covers 2.5 million hectares and has salinity as an increasingly significant problem.

The Perth Basin underlies about 2.5 million hectares, mostly in the West Midlands sub-region. It is a deep trough (possibly to 15,000m) of sedimentary layers and contains substantial groundwater reserves.

The Irwin Sub-Basin is an area of 0.6 million hectares - a narrow trough of sediments more than 5000m thick. The sedimentary sequences are dominantly fine grained resulting in poorly drained soils and saline groundwater.

The Northampton Block underlies 0.3 million hectares entirely in the Greenough sub-region. It is essentially a large outcrop of crystalline granitic basement partially capped in the southern and western areas by thin sequences of Mesozoic sediments. The soils are of high agricultural value.

The soil landscapes of the region are derived from mostly sedimentary rocks of the Perth Basin to the west and igneous and metamorphic rocks of the Yilgarn Block to the east that are amongst the oldest in the world (Anon, 2004). Large proportions of these landscapes have remained above sea level since the separation of Australia from Gondwana Land thirty million years ago and have been subject to dramatic climate changes including several ice ages. This has resulted in aggressive weathering over a long period of time, producing soils with deeply weathered profiles that are inherently low in nutrients and have an accumulation of salts deep in the profile (Anon, 2004). The soils thus contrast markedly with those of Eastern Australia and the Pacific region, which formed from volcanic rocks only a few million years ago, and those of other continents that are derived from recent sediments (Anon, 2004).

Such geological forces have also resulted in an extensive range of landscapes and soil types, with the soils in the region ranging from loose pale sands, to loams and heavy clays. Sandplain soils occur on the sediments west of the Darling Fault whilst hardsetting loams dominate in the incised valleys to the west of the Fault and on the lower and upper slopes of the broad valleys east of the Fault (Anon, 2004). Alkaline soils also occur in areas to the east that have experienced arid climates and on the coastal dunes where soils were formed from calcareous marine sediments. In the eastern part of the region, salt lakes have formed in the internally draining Yarra Yarra catchment and upper catchment of the Irwin River (Anon, 2004).

1.1.3 Climate

The NAR experiences a Mediterranean climate, with short, mild, rainy winters and long dry, warm to hot summers. Rainfall varies from 500 mm on the coast as far north as Geraldton to 700 mm at Lancelin in the south, down to 250-300 mm rainfall at the eastern and northern margins of the agricultural area.

Traditionally the Department of Agriculture WA (DAWA) has divided the South West of WA into climatic zones called 'Agzones' for the purpose of Crop Sowing Variety Guides, Figure 2. The 'Agzones' are defined based on the annual average rainfall for the region and the length of growing season. The rainfall zones are divided into high (H), medium (M) and low (L); separated by the >450 mm and <325 mm rainfall lines. These zones are further divided by the length of growing season from North to South (ie North having the shortest growing season being 1).



Figure 2: 'Agzones' of the South West of WA

However in the Regional Natural Resource Management (NRM) Strategy drafted by Northern Agricultural Catchments Council (NACC) this year, they identified the climatic zones slightly differently. They used the same H, M and L rainfall zones that defines the 'Agzones' but then further segregated these areas with reference to soil types, Figure 3.

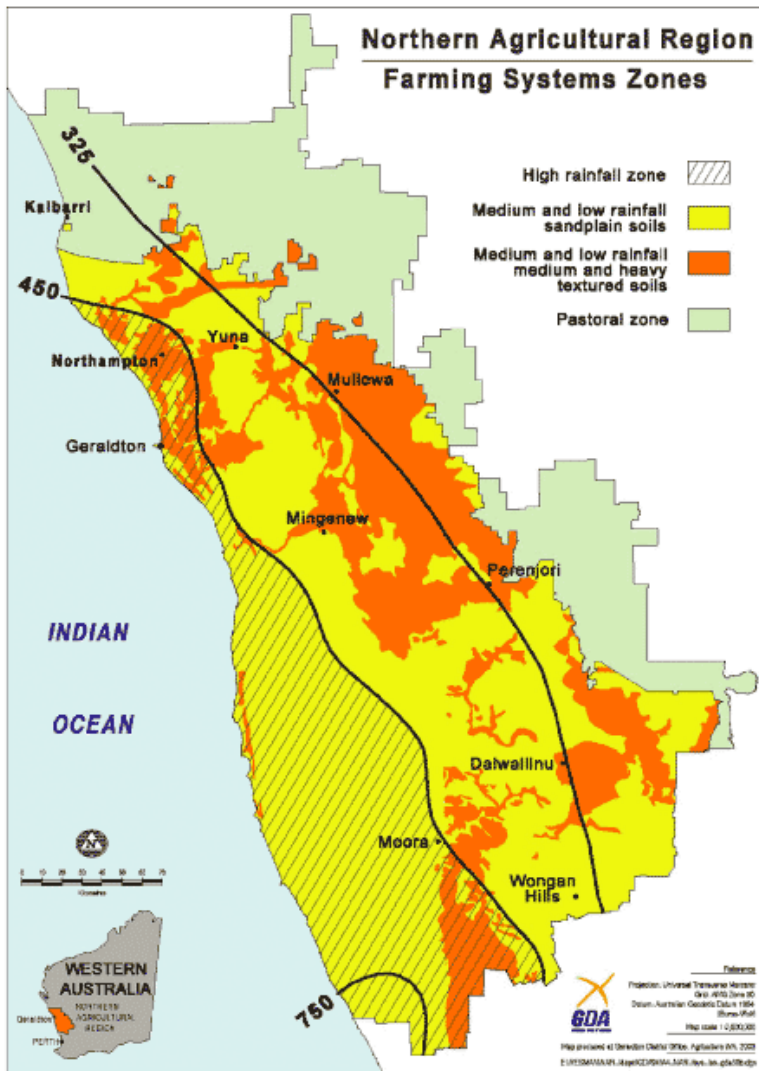


Figure 3: Climatic/Soil types zones for the NAR.

The NACC Regional NRM Strategy gave the zones the following characterisations.

1. High rainfall zone (HRZ) - broad acre cropping and grazing dominate, with increasing numbers of beef due to low land prices and the introduction of perennial fodder. Horticulture is expanding rapidly, particularly within 50km of the coast.
2. Medium and low rainfall sandplain soils (SS) - predominantly broad acre farming with reliance on wheat: lupin rotation. Although there has been a shift to cropping and reduction in livestock over the past 2 decades, the problem of herbicide resistance is resulting in a gradual recovery in livestock numbers in this zone.
3. Medium and low rainfall medium heavy textured soils (MHS) - predominantly broad acre farming with reliance on continuous cereal (wheat, barley, oats) production, with some pulse, oilseed and pasture rotational phases. Sheep grazing is also significant.
4. Pastoral Zone (PZ) - Traditionally and currently focused on wool production, with some harvesting of feral goats. Salinity and rising groundwater.

This map gives a broad indication of the soil types and climatic zones that the sub-regions of the NAR fall under.

1.1.4 Major Industry

Within the NAR broadacre agriculture is the pre-dominant industry, which accounts for 35% of the regional economy and is worth \$1000m annually. There is a growing diversity of agriculture where groundwater is available (Anon, 2004). Approximately half the region is cleared and cropped or pastured, supporting over 2000 agricultural enterprises. Broadacre farming predominates, and uses a wide range of soils and rainfall zones, including loam, clay loam and sandplain in the low (<350 mm) rainfall zone, loams and sandplain in the medium rainfall zone and duplex soils and deep infertile sands in the high (>450 mm) rainfall zone (Anon, 2004).

The dominant agricultural industries are wheat, lupins, wool, meat and other cereal and pulse grain crops. The region produces 35% of the State's wheat production, 50% of the State's lupin production and 10-15% of the production of oats and barley. There are a number of specialised horticultural industries, including citrus and stone fruit, mangoes, broadleaved and root vegetables, and floriculture. Many of these are expanding. There are also emerging aquaculture and farm forestry (based on *Pinus pinaster*) industries. Sheep and wool production in the region is significant and accounts for up to 20% of the state's production. Cattle numbers are low, but are increasing on areas of perennial pasture (Anon, 2004).

1.1.5 Traditional Broadacre Dryland Farming Systems

The farming systems vary from east to west. On the higher rainfall Midland sandplains to the south west, grazing with beef cattle and sheep is the dominant use. In the lower rainfall areas, and particularly on the extensive sandplains and valley floors to the east and north east, cereal and legume production dominates, with sheep being much less important in the farming system (Grain and Graze, 2004). Across all farms in the NAR, an average 1,250 hectares is sown to grains, which is well above the average for the other Grain and Graze regions, with wheat yields of about 1.7 t/ha being equivalent to the national average (Grain and Graze, 2004). Since the development of the cereal/legume rotation (wheat/lupin) in the 1970s, continuous cropping has become very important for increasing the productivity of deep yellow sands, which occur through the area. On average grain production generates about 65% of farm income, with grazing generating 15 to 20%, and off farm income returning about 10% (Grain and Graze, 2004). Cattle numbers have more than doubled in recent years, in response to declining returns from wool.

1.1.6 Traditional Pasture Systems

Traditionally annual pastures have been the most important source of feed in the Mediterranean environment of the agricultural region of Western Australia (Devenish K. and Hyder M., 2001). They consist mainly of either volunteer annual weeds such as capeweed, ryegrass, radish and volunteer crops from previous years or by sowing improved self-regenerating pasture varieties such as sub-clover, medics, serradellas and other new clover varieties.

The growth rates of young or adult sheep during winter and spring should be in the vicinity of 1.5-2.0 kg/head/week once there is ample green feed available (Devenish K. and Hyder M., 2001). The supply of green feed is often limited at the start of the growing season and consequently the growth rate for sheep is low (Devenish K. and Hyder M., 2001). Sheep feed is usually in abundance towards the end of the growing season and spring. At this time, growth rates of sheep are close to the maximum as possible.

Over summer, a dry annual pasture with about 50% legume content can only provide growth rates to young sheep of one to two kilograms per head per month for one to two months, because it is only slightly above maintenance ration. The rate of growth for weaners can vary considerably from December to April. At this time the digestibility of dry feed is the main influence on animal growth (Devenish K. and Hyder M., 2001). Dry residues of annual pastures like sub-clover, medic and serradella, along with weeds such as ryegrass and capeweed; usually have a digestibility of about 55% at the start of summer. The digestibility of dry feed can vary considerably depending on factors such as species composition, previous grazing, spray topping and fertiliser use. The quality of the dry feed will decline further over summer, especially after rainfall (Devenish K. and Hyder M., 2001). Dry feed with a digestibility below 55% will at best only maintain liveweight and supplementary feeding will be required to finish animals being produced for meat (Devenish K. and Hyder M., 2001). By autumn the dry feed will be of such poor quality that livestock will lose weight unless supplements are fed. The period of high quality pasture can be extended by spray-topping pasture with a knockdown herbicide in spring.

As well as feed quality problems, animal production is also restricted by limited feed quantity. Even after the break of season the overgrazing of annual pastures in autumn can lead to a significant reduction in green feed supply in early winter. Overgrazing in autumn reduces pasture seedling density, resulting in lower pasture productivity during winter because of reduced plant numbers. The solution to this is to defer grazing pasture at the break of season until Feed on Offer (FOO) is at least 500-800 kg of dry matter (DM) / ha (Devenish K. and Hyder M., 2001). Another important grazing method is to reduce grazing pressure at the start of flowering until seed maturity. Reduced grazing pressure is mainly required when FOO levels are less than 2000 kg DM/ ha (Devenish K. and Hyder M., 2001).

Self-regenerating annuals pastures like sub-clover, medic and yellow serradella, are best being used in intensive cropping systems. Hard seed annuals like medics and serradella are suited to being grown in rotation with crops where the crop phase may be one to four years long. Softer seeded pastures like sub clover will only persist when the crop phase is short (i.e. one to two years). Totally soft seeded species like Cadiz serradella will not persist through a single crop. Cheap and soft seeded species are now being used in 'pasture phases' where the pasture is resown after a cropping phase and is not expected to persist through the following crop phase. Phase pastures may also include self-regenerating annual species but the use of longer periods between crops also allows the use of perennial species such as lucerne.

These new innovations in annual pastures are being driven by cropping issues such as herbicide resistance and nitrogen from legumes, but will have a big impact on the animal enterprises on wheat belt farms.

1.2 CASE FOR PERENNIALS

1.2.1 Productivity

Reviewing the traditional annual pastures system raises some gaps as to where the introduction of perennial pastures would be very beneficial. With only annual pastures livestock growth rates are limited in autumn due the poor feed quality as well as quantity. After the break of season animals are limited by feed availability. At this time animals should be kept off the young annual pastures until there is adequate green leaf developed. At the break of season perennial pastures would already be actively growing and therefore can provide an alternative feed source giving the annual pasture a chance to 'bulk up.'

Another problem with the annual pasture system is that once the pasture senesces at the end of the growing season the dry feed begins to lose quality over the summer, resulting in animal production losses or the requirement of supplementary feeding. Perennials would be beneficial in this situation as they extend the growing season and stay green much longer after annual pastures have senesced. Therefore providing better quality feed for livestock throughout late spring/early summer period. Perennials can also make use of any summer or early season rainfall events and provide valuable extra feed. Perennials may also benefit the annual pastures because they can allow annual pastures to be destocked at critical periods. Reducing the grazing on annuals at flowering and break of season will increase their density and productivity.

Adding relatively small areas of perennial pasture into a farming system based solely on annuals can have a big impact. Wiley and Wilson (2004) report that even small areas of perennial pasture can significantly increase the whole farm-stocking rate. This is due to an increase in the autumn feed supply and also to unplanned changes in the grazing of the rest of the farm, which turn out to be beneficial. Grazing pressure on other paddocks with annual pastures was reduced in autumn and early winter when it is damaging and increased in winter and spring when it benefits annual legumes.

Generally perennials provide an extension of the green feed growing season and a good summer feed source, especially if a rainfall event is experienced.

1.2.2 Sustainability

Not only do perennial pasture species provide the opportunity for increasing productivity they also provide solutions to agricultural sustainability issues faced by farmers. Perennials can be beneficial to deal with problems such as herbicide resistance in the cropping phase, saline areas, poor soil health and increases in water use therefore allowing for less recharge.

To date little quantitative data has been recorded about the benefits, other than those that are production based, that can be gained from integrating perennials into the farming system, especially the environmental benefits. However, Grain and Graze aims to investigate the sustainability benefits of perennial pastures and to achieve some tangible outcomes in this area.

1.2.3 Perennials Integrated into Current Farming Systems

Not only do perennials provide the opportunity for increased livestock production, through extending the period of green feed, and increased sustainability of the farming systems, as stated above, they also provide solutions to various other agricultural soil problems. For example soils that cannot grow good crop or annual pasture such as saline, acid soils, deep infertile sands. These are the main reasons why the perennials species that have been introduced to farming systems in the past; in an attempt to overcome some of the most severe agricultural soil environments in the NAR. Generally this started with fodder crops such as Tagasaste for growth in the deep infertile sands and halophyte shrubs for saline areas.

1.2.4 Tagasaste (*Chamaecytisus proliferus*)

Tagasaste was introduced to gain production from the freely drained, poor deep sands of the West Midlands area of Western Australia, where annual crops and pastures struggle. Although tagasaste has zero tolerance for waterlogging or salinity it is able to grow in the pH range of approximately 4-7 (Wiley T., 2001). It can grow successfully in areas with annual rainfall of 300 to 1000mm. Tagasaste should be grazed lightly during the first two years but once mature it performs best with well managed hard grazing. It should not be set stocked with sheep for extended periods as they damage the new shoot buds and can kill the plants (Wiley T., 2001). Cattle can continuously graze tagasaste because unlike sheep they do not remove the new shoot buds. Tagasaste should be grazed or cut at least once in the first six months of every year to prevent flowering during the following spring. Flowering results in the leaves being dropped, a slowing of plant growth and a decline in palatability over the following summer (Wiley T., 2001).

Tagasaste can be grazed at any time of the year, however feed quality is best in winter and the poorest in autumn. In the West Midlands, tagasaste can produce between three and five tonnes of DM/ha/yr. Highest production will be achieved with good rates of superphosphate (200 to 300 kg/ha/yr) (Wiley T., 2001). Tagasaste growth peaks in spring and is lowest at the end of autumn, but will respond quickly to summer and autumn rain.

Feed Quality

Fertiliser trials have consistently shown that high rates of phosphorous fertiliser are required for maximum animal growth rates. At Dunmar Research Station, Badgingarra, an extra kilogram of liveweight/ha was gained from cattle with every extra kilogram/ha of superphosphate applied, up to 300 kg/ha (Wiley T., 2001). This occurs because phosphorous fertiliser improves the feed quality of the tagasaste resulting in an increased feed intake by the animals. While growth rates of both sheep and cattle were minimal in autumn, the higher rates of superphosphate meant that animals were still gaining weight slowly rather than losing weight (Wiley T., 2001).

In tagasaste, protein, digestibility and most minerals are highest in winter and spring and then gradually decline over summer. During winter and spring, tagasaste is very good quality feed and animal growth rates are as good as on any other green feed. No supplements are required at this time of year. By late autumn animals on tagasaste will only be maintaining condition (Wiley T., 2001). At this time of year protein is the limiting factor for animals despite it never dropping below 14 percent in the tagasaste leaf. Trials and farmer demonstrations have shown that supplementing tagasaste with a good protein source (ie lupins) will boost

animal growth rates in autumn. Additional to this, a well-balanced salt-lick may also need to be supplied in autumn, due to a decrease in the mineral concentration of tagasaste (Wiley T., 2001).

Tagasaste compared to annual pasture in the West Midlands

Trials conducted for the Martindale Research Project, found that 100 sheep could be fed for 30 to 40 days on tagasaste that had been locked up for 11 months. This was equivalent to a year round average of eight to ten DSE/ha/year (Wiley T., 2001). This is a considerable improvement for these poor sandy soils that previously carried only one to two DSE/ha/year with annual pastures. However in this trial the sheep were only maintaining liveweight in autumn (Wiley T., 2001). Lupins are required to enable sheep to grow at this time of year. A whole farm analysis based on performance on the Dunmar Research Station has shown that tagasaste is profitable when it is used to replace supplementary feeding of sheep with grain in autumn (Wiley T., 2001).

These results show that the perennial fodder shrub tagasaste has proven to be a profitable investment for the areas of Western Australia with poor deep sands that could not produce reasonable annual crops and pastures.

1.2.5 Perennial Salt Tolerant Halophyte Shrubs

Saltbush (*Atriplex sp.*) and Bluebush (*Maireana brevifolia*)

Saltbush has been adopted widely throughout the whole South West of WA, for plantings on saline affected land since early work was done in the 1980's. There is extensive information available regarding halophyte shrubs. Halophytes generally have low grazing value as they accumulate large amounts of salt in their leaves. Animal performance on straight salt bush is limited by the excessive amount of NaCl in their diet. However the salt bush can lower the water table and alter the micro-environment to allow the establishment of other pasture plant species (Lacey T., 2001). These other species have lower levels of NaCl and dilute the salt levels in the animal's diet. Salt bush has mostly been planted in locations where there is no alternative land use (ie salinity or waterlogged affected areas) and they can be used at times when other feed sources are scarce or expensive. Saltbush and bluebush have high nitrogen concentrations, significant levels of fibre and but also contain high concentrations of salt.

The value of forage is determined by the following components of the pasture; digestibility, ash concentration and total Nitrogen. Digestibility provides a measure of the availability of energy from the forage and is expressed as a percentage. A non-saline diet with a digestibility of 55% is required for the maintenance of a non-breeding sheep. In general salt tolerant shrubs contain amounts of energy which are suitable for maintenance, but not growth (Barrett-Lennard E. and Malcolm C., 1995). Also the maintenance energy for sheep grazing on saltland shrub diets may be greater on the whole, with extra energy required for salt excretion due to high concentrations of salt in the diet. As the animals have greater need for water they need to expend more energy walking between grazing plants and the watering point, and forage shrubs are a low density feed, therefore the animals will spend more time seeking and consuming the diet than conventional pastures (Barrett-Lennard E. and Malcolm C., 1995).

Ash concentration for good performance sheep diets should contain less than 5% salt. In general, leaves of halophytes have high concentrations of chloride, sodium and potassium (Barrett-Lennard E. and Malcolm C., 1995). These minerals play an important role in the osmotic adjustment of the plant and are essential for their growth in saline and arid conditions. Grazing trials at Katanning have shown that saltbush alone is of limited value because high salt concentrations reduce the dry matter intake and digestibility of the material (Lacey T., 2001). In general sheep are only able to consume approximately 200 g of salt per day. This means they are unable to eat more than about 700 to 800 g of saltbush per day. This is not usually enough to meet the sheep's requirement for growth (Norman H., 2004). Most nitrogen in grass pastures is digestible. However nitrogen in saltland shrubs includes a substantial proportion of non-protein nitrogen, which although it is available can be excreted if there is insufficient energy in the diet (Barrett-Lennard E. and Malcolm C., 1995). While lab tests of salt bush usually indicate high Nitrogen levels, and therefore high Crude Protein, this may not be a true reflection of what animals can extract from a salt bush diet.

Saltbush needs to be supplemented with less salty feed to get the best animal performance. In stands of halophytic shrubs, sub-storey grasses can be the major component of the forage available. Under these conditions diet quality and quantity will be affected by the composition and amount of the sub-storey (Lacey T., 2001). The animal weight gain in a salt bush stand will often relate closely to the quantity and quality of sub-storey plants.

Saltland pastures can be improved if you include an inter-row species with a higher feed quality. For example perennial grass species such as puccinellia or tall wheat grass have been used as inter-row species in the past because they have higher digestibility and lower salt content than saltbush but are not necessarily high quality feeds (Lacey T., 2001). Whereas if this site was suitable for a salt tolerant annual pasture such as Balansa clover or Scimitar medic these legumes would provide a much higher quality feed even when dry. Although it may take a few years from the initial saltbush establishment before the micro-environment becomes suitable to grow these annual pastures. Improved saltland pastures with a good annual pasture inter-row can grow weaners at up to 100 g/day (0.7 kg/head/week) over summer without supplementation (Lacey T., 2001). However it is always site dependent and many of the improved annual pastures will not be able to tolerate the waterlogging and level of salinity at sites where saltbush is grown.

This is reflected in a study by Norman H *et al.*, 2002, where a mix of Wavy leaf, Oldman and Creeping saltbush was grown with inter-rows of balansa clover and volunteer capeweed (4 m of saltbush and 8 m of Balansa). The site was stocked at 8 DSE/ha for 74 days. Weight measurements were taken at 0, 19 and 74 days. They found that the sheep preferentially grazed the Balansa until it had all been removed at the end of the 74 days. The weaners gained 80 ± 10 g/day for the first 19 days of grazing. After this period the Balansa dry matter was reduced to 240 kg/ha and then over the next 54 days the sheep lost 8 ± 4 g/day liveweight.

Saltbush is most profitable as a perennial feed during summer and autumn when alternative feed supplies are limited. Salt bush may offset the need to supplementary feed stock through autumn, and thus enable grazing to be deferred on newly germinated annual pastures (Lacey T., 2001). In this way, higher stocking rates can be achieved across the whole farm. The best returns are likely to be obtained where substantial

increases in stocking capacity are achieved through the conversion of very low performing land to land with a much higher production level and in the reduction of some supplementary costs (Lacey T., 2001).

Care needs to be taken when weighing animals grazing on salt bush. The high salt intake by sheep on salty diets increases water intake by the sheep. Sheep on saltbush diets can drink up to 8L of water/kg of DM intake/day (Barrett-Lennard E. and Malcolm C., 1995). The salt in the diet also increases water retention in the tissues. These increases may mask decreases in 'water free' tissue weights. Animals may 'gain weight' on salt bush simply due to the extra water retained rather than true body growth. Body condition scores appear to be far more reliable indicator of animal condition (Barrett-Lennard E. and Malcolm C., 1995).

1.2.6 Lucerne (*Medicago sativa*)

Lucerne has generally been sown throughout the South West of WA as a high water use species that has the ability to reduce recharge and for its capacity to extend the growing season of traditional annual pastures. Lucerne requires at least 250 mm of annual rainfall to persist. It is best suited to well-drained soils with a pH between 4.8 and 8.0 (Lacey T. and Devenish K., 2001). Winter active varieties of lucerne are preferred for dryland sowing in WA. The winter active varieties establish better but may not persist as well as winter dormant varieties. However the better winter active varieties should persist for the four to five years required in a pasture phase. Winter dormant varieties are used for irrigated crops only. Under irrigation they last for many years but are never grazed. These hay only varieties usually do not tolerate grazing well.

For an average rainfall season, lucerne will provide extra green feed earlier in winter and extend the availability of green feed at the end of the growing season (Lacey T. and Devenish K., 2001). Generally lucerne will not increase the amount of late winter or spring pasture supply when compared to a straight annual pasture. The amount of summer (January to April) feed production depends on moisture availability from either summer rainfall or stored soil moisture. Lucerne can rapidly convert summer/autumn rainfall into high-quality green feed whereas summer rain will reduce quality of dry feed and can cause a 'false-break' in annual pastures (Lacey T. and Devenish K., 2001).

The quality of feed available from lucerne remains relatively constant throughout the year. Lucerne pastures are capable of producing levels of total biomass comparable to or better than good annual pasture (eg sub-clover) over a 12 month period (Lacey T. and Devenish K., 2001). Lucerne supplies feed of a much higher value over the summer/autumn period than that of annual pastures. The significance of these attributes to sheep meat production is the flexibility to turn stock off into high priced markets either early or late in the normal growing season. Lucerne provides high quality feed for grazing animals. It is highly digestible (approximately 65 - 85%) and is a reliable and economic source of crude protein (12 to 24%) with good levels of metabolisable energy (8 to 11 mega joules/ g of DM) (Lacey T. and Devenish K., 2001).

For best results, lucerne should be rotationally grazed if it is to persist in a grazing system. For sheep, the grazing rotation can vary from a three paddock system (lucerne grazed for three weeks and rested for six weeks), to a six paddock system (lucerne grazed for one week and rested for five weeks) (Lacey T. and Devenish K., 2001). Set stocking is not advisable for dryland lucerne because sheep will constantly select

and graze the lucerne plants, thus reducing their vigour. Trials in the wheatbelt have demonstrated that lucerne can support average district stocking rates while providing additional green feed after annual pastures have matured. Growth rates of more than 1 kg/week can be expected from sheep grazing on dryland lucerne. Growth rates of 1.13 to 1.75 kg/head/week have been measured at three wheatbelt sites in WA, as shown in Table 1 (Lacey T. and Devenish K., 2001). All sites were set up with the three paddock system and stocking rates have been averaged over the three paddocks.

Table 1: Sheep growth rates on dryland lucerne at three sites in the wheatbelt using a three-paddock system

Location	Grazing period	Stocking rate (hd/ha)	Initial weight (kg)	Final weight (kg)	Grazing days	Weight gain (kg/hd)	Weekly growth (kg)
Morawa	Sep-Nov '99	6	45.5	59.0	84	13.5	1.13
Mingenew	Jul-Sep '00	10	45.0	58.5	66	13.5	1.43
Dandaragan	Feb '00	12	-	-	18	4.5	1.75

These are an example of perennials that have been widely used and studied in the past, but each of these has their limitations. In more recent years we have been looking towards Sub-tropical perennials grasses to fill the spot of finding a successful perennial pasture.

1.3 CASE FOR SUB-TROPICALS

Plants can be classified into two groups based on their variations in the photosynthetic pathway and the structure of the chloroplasts (Knox *et al.* 1997). There are two photosynthetic pathways that legumes and grasses use. The most common pathway is the C₃ pathway, so called because the first stable product of photosynthesis is a 3-carbon acid, phosphoglyceric acid (PGA). This pathway is used by all temperate grasses and legumes, and by tropical legumes. The photosynthetic process of C₃ plants involves the Calvin-Benson cycle in the stroma of the chloroplasts, described fully by Knox *et al.* 1997; Raven *et al.* 1992. The most pertinent feature of this cycle is the involvement of the CO₂ acceptor molecule, Ribulose biphosphate (RUBP) and its companion enzyme Ribulose biphosphate carboxylase-oxygenase (Rubisco) (Humphreys 1981; Knox *et al.* 1997; Raven *et al.* 1992).

Most tropical and sub-tropical grasses use a C₄ photosynthetic pathway, so named due to the first stable product of photosynthesis being a 4-carbon acid, malic and/or aspartic acid. The CO₂ acceptor molecule of the C₄ pathway is Phosphoenolpyruvate (PEP) and its companion enzyme is PEP-carboxylase. Malate, or aspartate, depending on the species, is decarboxylated to yield CO₂, which then enters the Calvin-Benson cycle (Humphreys 1981; Knox *et al.* 1997).

1.3.1 The effect of C₃ and C₄ pathways on photorespiration and water stress tolerance

The major difference between the two systems is in their efficiency in fixation of CO₂. Photosynthesis in C₃ plants is accompanied by photorespiration, a process that consumes O₂ and releases CO₂ in the presence of light (Raven *et al.* 1992). In O₂-limited environments, such as those that existed during the development of plants, the C₃ pathway is very efficient. However, depending on the relative concentrations of O₂/CO₂, the CO₂ acceptor enzyme, Rubisco, can use O₂ as a substrate rather than CO₂. Under normal atmospheric conditions, where O₂ is much more abundant than CO₂, as much as 50% of carbon fixed during photosynthesis by a C₃ plant may be reoxidised to CO₂ during photorespiration, therefore limiting the efficiency of the photosynthetic system (Raven *et al.* 1992). This means that the stomata have to be more fully opened to gain enough CO₂ and therefore allowing more H₂O to escape.

This process of photorespiration is nearly absent in C₄ plants (Raven *et al.* 1992). The initial CO₂ acceptor companion enzyme, PEP-carboxylase, is much more reactive with CO₂ than Rubisco, therefore no CO₂ is lost in the initial fixation process. When the initial C₄ cycle is completed, the product CO₂ is effectively pumped into the bundle sheath cells (where the Calvin-Benson cycle takes place), ensuring a high CO₂/O₂ ratio and maximum Rubisco efficiency (Humphreys 1981; Knox *et al.* 1997; Raven *et al.* 1992). As a result of this improved efficiency Raven *et al.* (1992) observed that net photosynthetic rates in C₄ grasses can be 2-3 times the rates of C₃ plants under the same environmental conditions.

1.3.2 Limitations of C₃ (temperate perennial) species

To overcome high water requirements in drought conditions, cultivated C₃ grasses in Mediterranean zones of Europe and northern Africa rely on root penetration and moisture acquisition to overcome problems posed by high water requirements (Johnston 1996). Once moisture reserves are depleted perennial C₃ grasses rely on leaf senescence and dormancy to offset high evaporative demand in summer conditions when moisture availability is low (Johnston 1996). As a result, although this species will persist through drought periods, the dormant growth habit and lack of leaf material decreases the material available for summer forage. This is not an ideal situation as the one of the main reasons for the proposed introduction of perennial species into a Mediterranean environment is to provide an extended period of green forage. Compounding this is the problem of persistence generally declining if their inherent need for adequate moisture is not met over an extended period of time.

1.3.3 Benefits of C₄ (sub-tropical perennial) species

A review of literature by Jones (1985) indicated that C₄ plants are proportionally more abundant where summer temperatures are relatively high and moisture availability is relatively low, suggesting that warm, dry conditions confer a competitive advantage to C₄ species. Johnston (1996) summarises the functional aspects of the C₄ photosynthetic pathway as “essentially a CO₂-concentrating mechanism, which by operating at low stomatal conductance, allows carbon (C) fixation at much lower water cost than with C₃ plants.” The practical advantage of adaptation is that in conditions typical of summer in subtropical and dryland Mediterranean environments (high temperature, light intensity and evaporative demand), the C₄ pathway provides water use efficiency unmatched by C₃ plants, therefore giving C₄ plants a competitive advantage. These features have allowed the C₄ group of grasses to have a greater adaptive range than the C₃ group of plants.

1.3.4 Why are C₄ (sub-tropical) species suited to the NAR

The Mediterranean climate of the NAR gives C₄ species the competitive advantage over C₃ species for two reasons. One; because the plants have a higher water use efficiency they are able to survive the hot dry summers and two; because the winters in the NAR are relatively mild.

Sub-tropical perennials exhibit a growth feature that can cause them become generally dormant during the cooler growing months in Mediterranean climate where they have previously been introduced, however winter temperatures in the northern agricultural region of Western Australia are far milder than those experienced in New South Wales and southern Queensland, with higher average minimum temperatures and an absence of extreme lows, through the winter periods (Kemp 1975; Kemp and Dowling 1991; Bureau of Meteorology 2002). Because of this, it may be expected that winter growth of tropical species would not be so severely depressed in the Western Australian habitat. Subtropical species that are able to persist through winter will also be able to flourish in the warmer spring period when the Mediterranean crops and pastures have set seed, died, or become dormant. This will allow for a longer period of green fodder throughout the year. As subtropical species are also able to flourish on warm season rainfall, any out of season falls in a Mediterranean environment can be exploited, possibly giving year round growth.

SECTION 2: AGRONOMY OF SUBTROPICAL PERENNIAL GRASSES

2.1 SPECIES SELECTION

There is abundant literature based in the eastern states of Australia describing the suitable species and varieties of perennial pastures for various conditions (www.dpi.qld.gov.au and www.agric.nsw.gov.au). Through consultation with growers and industry experts from the eastern states, the local industry has found some species to be successful in areas where they would be expected to fail. Green and Gatton panic and Signal grass are three species that have successfully adapted to very poor sands in WA, where as in the eastern states it is considered they will only persist on soils with very high fertility (McDonald, 2003).

Because of these observations, eastern states recommendations have had to be taken as a guide only, and extensive variety testing has been carried out over a wide range of environments and soil types. This testing is ongoing as the success or failure of a pasture can be attributed to varietal characteristics, seeding techniques and/or seasonal conditions. The core species that are being used in the Northern Agricultural Region has become fairly stable in the past few seasons, and are generally selected because of their continuing success in plot and farm-scale trials.

Rhodes grass (*Chloris gayana*) is a summer-growing, tufted perennial that spreads well by above-ground runners. Rhodes grass can be grown over a wide range of soil types from light textured sandy loams to heavy textured soils. Rhodes grass combines well with annual legumes. It is moderately frost tolerant and has reported salt tolerance, but is not tolerant of waterlogging. Rhodes has a very light and fluffy seed that makes it difficult to handle. The seed needs to be mixed with a carrier or coated, to enable it to flow through seeding machinery.

On soils where there is a shallow (<3m) water table, Rhodes can be very productive. On dry sites, it can become moisture stressed in late summer, but will not die out.

Rhodes has performed well under grazing systems in Western Australia. The quality of the grass decreases rapidly with flowering, so good grazing management has been found to be necessary to get the most out of the stand. It also has added benefits on lighter soils as its running growth habit gives it good soil stabilisation attributes.

There are a number of cultivars of Rhodes grass that have been evaluated in Western Australia. Callide is the latest flowering and most productive cultivar of Rhodes grass; however Katambora, Finecut and Topcut have much better salt tolerance than Callide. Pioneer is the earliest flower cultivar and has been the least productive in WA trials. Nemkat is nematode resistant but has not yet been tested in Western Australia (Wiley *et al*, 2003).

Green and Gatton Panic (*Panicum maximum*) are bunch grasses that will only spread by seed. Green and Gatton have fine, soft leaves and slender stems that are very palatable. They can grow to a height of 1.5m and have a richly branched root system that facilitates rapid growth after light showers of rain.

Green and Gatton Panic are good performers on drier, light soils. Green Panic has been the best performer on the poor white sands. These panic species are not well suited to very heavy soils and do not have much waterlogging tolerance, however they have been found to be suitable for most other situations (Wiley *et al*, 2003).

Green and Gatton Panic are very palatable and are usually grazed preferentially in a mixed sward. Sparse stands will thicken up if allowed to seed and a damaged stand will regenerate from natural seeding. They will persist if managed properly and the pastures are not set-stocked. These panics are the species that gives the best germination following autumn rains.

Bambatsi Panic (*Panicum coloratum*) has bluish coloured leaves with a prominent white midrib. Also known as Makarikari grass. Bambatsi has erect to semi-prostrate growth. It establishes well on a wide range of soil types and, although it may not produce as much biomass as other grasses, it is usually more palatable and has higher nutritional value. Bambatsi is very persistent once established but has poor seedling vigour.

Bambatsi Panic is not as productive as other subtropical grasses but has exceptional waterlogging and drought tolerance. It has also persisted very well on heavy soils where other species can struggle over dry summers. Bambatsi should be included in mixes for difficult sites. Bambatsi has been one of the better performing grasses in Western Australia once established.

Setaria (*Setaria sphacelata*) is a tall bunch grass that spreads by seed. It is a tufted grass that can grow to a height of over two metres with a spike-like flower head. It has performed well on a wide range of soils, including acid soils. It has good waterlogging tolerance but is not quite as drought tolerant as the Panic or Rhodes grasses.

Setaria is well accepted by cattle but has a rather low sodium content and high oxalate content, especially if fertilised with nitrogen, meaning that care must be taken with stock grazing lush, Setaria-dominant pastures.

Splenda and Solander have been the most successful cultivars of Setaria in WA. Setaria has been one of the more successful perennial grasses grown in Western Australia and is generally included in most mixes.

Setaria has the best winter production and frost tolerance of the sub tropical grasses tested in WA so far.

Signal Grass (*Brachiaria decumbens*) is a fairly prostrate, bunching grass species. It is one of the newest subtropical perennial grass species being investigated in Western Australia and performed well over a range of soil types in 2003 and 2004. It is a bunching grass that can also spread from runners, giving good ground cover. It is reported to be highly responsive to soil fertility

Signal gives good production over summer but has very poor winter production. It will be totally burnt off by the first frost but will grow again the following summer. Whilst Signal is relatively drought tolerant, it can only

handle waterlogging for a short period of time. In Queensland, Signal grass has been observed to be very competitive with weeds, even in low fertility areas. This is due to the dense cover it can form.

Premier Digit Grass (*Digitaria eriantha*) is a fine-leaved bunch grass that can send out runners occasionally. Limited testing of this species has occurred in Western Australia, however it has shown very good drought tolerance in the low rainfall conditions of the eastern wheatbelt.

Kikuyu (*Pennisetum clandestinum*) is a prostrate perennial grass that spreads by both above- and below-ground runners.

Kikuyu grows across the landscape on the south coast but was thought to be confined to summer wet patches in northern regions until recent trials suggested it might be more versatile.

It is very tolerant of hard grazing, and as such is the most tolerant species to set stocking. New plantings of kikuyu are more highly palatable and nutritious than established stands. However, its feed quality is at the poorer end of the range of the perennials, and kikuyu must be hard grazed regularly to maintain a modest quality and to allow annual legumes to survive in the stand

Other Species

There is a wide range of other subtropical grasses. Grasses that have been tested in WA include: Creeping Blue Grass, Jarra Digit Grass and Strickland Finger Grass. Generally, they have not been as impressive as the grasses listed above. However, some may have potential in low rainfall areas or on heavy soils. Some of these species have been included in recent trial work in the Northern Agricultural Region over the 2004/05 summer.

2.2 ESTABLISHMENT

The approach for establishing perennial grasses in Western Australia was originally derived for the subtropical regions of eastern Australia. The major principles for establishing grasses still apply to the Northern Agricultural Region of W.A. i.e. weed control, seedbed preparation and seeding depth. These ideas have gradually been adapted to the local conditions to account for soil type, machinery and climatic differences. The approach to establishing grass pastures in eastern Australia is well documented. One such resource used in W.A. is 'Tropical grass seed production-A training manual', compiled in 1996 by the Queensland Department of Primary Industries.

2.2.1 Soil type suitability

Most literature based in the eastern states (McDonald and Bowman, 2002; Keys and McDonald, 2002) suggests soil fertility is a major factor in the success and productivity of a perennial pasture. In almost direct contrast, local evidence suggests that whilst perennial grasses can be established on a range of soil types, those sown on deeper sand tend to have a better establishment and are more productive than perennials sown on shallow sand over clay, loams or clays (Wiley, 2002,unpublished).

Based on conservative adoption rates, Moore *et al* (2003) suggest that there are potentially 855,000ha that could be sown to perennial grasses in the southwest land division of Western Australia. The soil types with the highest potential for subtropical perennial grasses are the summer-moist and winter-waterlogged soils, predominantly found in valley floors in the medium to high rainfall zones. Deep leached sands, some with gravel at depth have also proven to be highly suited to these species, presumably due to the rooting characteristics of the perennial species being able to access moisture and nutrients at depths that annual species cannot. Marginally saline soils in the medium to low rainfall zone are often characterised by extra moisture in the profile that can potentially be accessed by the more tolerant grasses such as Rhodes grass and *Bambatsi panic* Moore *et al* (2003).

2.2.2 Time of sowing

Defining the ideal sowing dates is an area that has required ongoing assessment. Initially, eastern states information suggested that sowing in September-October, when soil temperatures were '18°C and rising' was the most reliable guide (McDonald and Bowman, 2002). In the subtropics, this timing allowed for an increasing chance of reliable rainfall post-seeding, avoided late winter frosts, and circumvented the mechanism present in many subtropical species that prevents germination at low soil temperature. In the west midlands area, where the grasses were initially planted, this soil temperature equates to a mid-late September planting. Through a better understanding of the local climatic conditions and crop's growing requirements, this has been refined to sowing in late August in the north of the region and early September in the south (Wiley *et al*, 2003). Further trial work recently conducted by the Evergreen Farming Group in conjunction with Department of Agriculture Western Australia, suggests that seeding in early August (2004) caused much higher germination numbers across a range of species than later sowing dates (Wiley *et al*, 2005). In that trial there was evidence of some preconditioning of seed that had been in the soil for a longer period of time as there was no germination in the trial until a significant rainfall event that fell immediately after the last seeding date. Soil temperature (9.00 am) was recorded at the site and indicated that emergence did not occur until the soil was consistently above 15°C (Wiley *et al*, 2005).

Another option that requires further research is the possibility of sowing opportunistically in autumn. Unlike the subtropics of northern Australia, the late autumn period in the NAR maintains soil temperature whilst generally being a period of increasing rainfall reliability. The down side to this method is the competition from vigorous annual pastures and weeds could smother and kill the fragile perennial seedlings.

2.2.3 Paddock preparation

Throughout the literature (Keys and McDonald, 2002 and McDonald and Bowman, 2002), and with the support of local evidence, it has become clear that inadequate weed control is the biggest cause of failure when establishing subtropical grasses. Because of the poor competitive ability of young seedlings it is essential to achieve a complete weed kill prior to the sowing of subtropical grasses. An added benefit of obtaining full control of annual pastures well in advance of sowing is the retention of moisture in the soil profile. With moisture retained in the profile, local evidence suggests that one post-seeding rainfall event to stimulate germination can be enough to establish a pasture (Wiley *et al*, unpublished).

2.2.4 Herbicides strategies

At present the knowledge on herbicide options for use on perennial grasses is limited compared to other crops. Using a non-selective chemical before seeding is the most widely used herbicide strategy within the industry. Using a single or double 'knockdown' generally provides adequate weed control to ensure establishment. Because of the planning and advanced preparation required for this strategy there are two major limitations. Firstly, late decisions to sow (or not sow) perennial grasses are unlikely to be made, as there is a requirement to spray approximately 1 month in advance of seeding. A sudden deterioration or improvement in seasonal rainfall cannot be acted upon. Secondly, there is a significant loss of grazing in the paddock to be sown if the annual is sprayed at the beginning of the spring flush.

Because of these limitations, there is requirement to identify pre-emergent selective herbicides that could potentially be used. There has been very limited trial work conducted on local soil types, with local machinery, to determine which herbicides may have potential for future use.

Some preliminary trial work was conducted by Rogers (2003) to determine the tolerance of an established subtropical grass pasture to various selective herbicides. This work has helped to gain an understanding of the potential weediness of some of the grass, although anecdotal evidence suggests that the plant's response to a chemical application is strongly dependent on seasonal conditions and growth stage. At present, none of the pre-emergent or post-emergent selective herbicides on the market are registered for use on subtropical grasses, further indicating the lack of research into the area.

2.2.5 Sowing Method

Locally, it has been shown that subtropical grasses can be sown with most seeding equipment. In the raw form, some perennial grasses are 'fluffy' and don't flow through seed boxes without some form of carrier. Rhodes grass is especially bad for this trait and many seed suppliers are now coating Rhodes grass to improve flow ability.

As the industry has developed in W.A. growers from outside the traditional grazing belt along the coast have been able to make use of more sophisticated machinery such as air seeders. Experience thus far suggests that sowing depth may be the critical factor in determining the pasture's final composition when sowing grass mixes. A recent trial at Irwin, W.A. found that emergence of different grass species was directly affected by sowing depth. At a sowing depth of 0cm, Rhodes grass (2 plants/m²) germinated more readily than signal grass (1plant/m²). At 2cm depth the emergence of signal grass was better than Rhodes (3.5 and 0 plants/m² respectively) (Wiley *et al*, 2005). Poor conditions at the time of the trial accounted for the generally low germination rates, however the results indicate the effect of seeding depth on the final sward competition. Rhodes grass has a much smaller sized seed than signal grass, which suggests that the increased seed energy and coleoptile length of signal allows it to emerge from a greater depth. This result has been observed at a number of farmer demonstration sites across the Northern Agricultural region.

2.2.6 Tillage

The soil type that has been the focus of much of the farm research in the Northern Agricultural Region is poor grey/white sand. The defining properties of this soil type are poor nutrient and water holding capacity and a non-wetting topsoil. Using a combination of local knowledge and advice from eastern Australia, the most widely used tillage practice for sowing perennial grasses has been a knifepoint with minimal topsoil cultivation, followed by a press-wheel to aid seed soil contact. Recent farm scale demonstration on this soil type suggest that there may be improvements in establishment to be made by alleviating the non-wetting problem by removing some, or all of the topsoil out of the seed zone. The potential benefits of this system may be threefold. Firstly, the non-wetting soil is removed so that seed is placed in soil that will 'wet-up'; secondly the this practice will create an exaggerated furrow which will allow small rainfall events to be magnified; and finally, all weeds seeds will be scalloped into the inter-row with the non-wetting soil, which should create a delayed germination of competitive weeds. This third point may be particularly beneficial in autumn sowings to reduce competition from winter weeds.

This tillage technique has been observed at a farmer demonstration level with both tyned and disc machinery. However, these observations have yet to be tested scientifically and require replicated trial work to remove the vagaries within sites that can affect the success of different establishment methods.

2.2.7 Sowing rate

The recommended rate for sowing subtropical perennial grasses is 2–4kg/ha. A seeding rate trial conducted in 2004 at Irwin, found that the number of plants established increased directly with seeding rate. Averaged over all grass species sown, 1.08 plants/m² established per kilogram of seed sown (Wiley *et al*, 2005). This result is much lower than would be expected and is probably due to a number of factors. i.e. extremely poor, non-wetting soil with poor moisture retention in the topsoil, and light rainfall events immediately after seeding followed by hot, dry winds. The minimum density of seedlings required for establishing a subtropical perennial grass stand has not been accurately defined and further trials should aim to match seeding rates to soil types and seeding conditions.

2.3 FARMING SYSTEMS

2.3.1 Grazing management

Trial work into the most effective grazing system for perennial pastures in Western Australia has been very limited. General grazing principles have been derived from eastern states information and are based on maintaining the long-term health of the pasture. McDonald and Bowman (2002) suggest the most specific management is required in the establishment phase to ensure productivity is maximised for the life of the pasture. At this stage, seedlings are extremely fragile and are easily pulled from the ground. Keys and McDonald (2002) also commented on the ongoing deficiencies that are often observed in pastures that have not been allowed to establish.

Grazing principles described identified in the PROGRAZE® manual (Meat and Livestock Australia, 2001) suggest that some form of rotational grazing for at least part of the year would be advantageous. In Western Australia, the 'autumn feed gap' is a period when green material on perennial pastures is particularly susceptible to patch grazing by livestock, especially sheep. During this period a graze and rest regime will prevent this and reduce the depletion of root reserves (Wiley, 2001). Perennial grasses tend to benefit from being allowed to seed periodically. This allows root reserves to be replenished and provides seed for regeneration (McDonald and Bowman, 2002).

On highly productive wet areas stock can graze the grasses at extremely high rates for short periods of time using temporary electric fences to cell-graze. However, on the south coast of Western Australia, continuous grazing of kikuyu grass over summer at high stocking rates has been successful. Kikuyu is the perennial grass species that is best adapted to set stocking. Other sub tropical species may not be able to tolerate continuous set stocking. More work is required to determine the affect of different grazing rotations on a range of perennial species.

The grazing management may not only impact the perennials directly, but also affect their companion legumes. A species such as sub clover, that does the best under continuous hard grazing, may disappear from a paddock being rotationally grazed. Other more upright annual legumes could be favoured by rotational grazing.

2.3.2 Grazing Frequency

Once established, most perennial pastures persist well under some form of rotational management. Whatever the grazing system, paddock management should aim to avoid rank growth in summer and autumn. Farm-scale animal production records show that if plant growth is not controlled the pasture will deteriorate in quality and palatability, animal growth rates will be disappointing and the legume component will decline (Wiley, 2001). A later section of this paper will discuss the effects of cutting (grazing) frequency and palatability and forage quality of perennial grasses.

2.3.3 Sheep vs cattle

The literature suggests that there is no definitive answer to whether sheep or cattle are more suited to grazing perennial pastures. Grazing by cattle will generally be 'softer' on the pasture than grazing by sheep. If sheep are to be used on perennial grass pastures, especially in dry periods with no other green material, active management is required to ensure that the plants are not damaged. Cattle will generally not graze low enough to remove all green material, and some perennial species can adapt under heavy grazing to produce a lot of material at ground level.

Grazing systems based on using optimum Food On Offer (FOO) measurements will find that sheep are able to graze perennial pastures earlier after the 'break-of-season' than cattle. On some sites this may allow more moderate stocking rates for a longer period, therefore still maintaining grazing intensity without doing damage to plant root reserves.

2.3.4 Forage Quality and Animal Production

There are a number of factors that influence the productivity and forage quality of subtropical perennial grasses. Seasonal conditions, growth stage and fertiliser nutrition are some factors that play a large role in animal performance on these pastures. There has been limited published experimental work conducted in Western Australia to quantify some of these differences, with most observations being derived from paddock scale demonstrations or anecdotal evidence. Romero and Siebert, 1980, found that organic matter digestibility (OMD), and therefore digestible energy, of buffel grass (*Cenchrus ciliaris*) and sabi grass (*Urochloa mosambicensis*) was highly correlated with weight gain of grazing cattle in tropical Queensland. Therefore, in the dry season, when digestibility decreased, energy levels were the factor limiting animal performance and often fell to levels below that which is required for maintenance. Following rain, digestibility of the material consumed by the animal increased by over 50% to 63% (Romero and Siebert, 1980).

The seasonal constraints of the Northern Agricultural Region mean that growth of perennial grasses is almost exclusively in the dry season, indicating that energy levels of pastures during this period may limit animal performance. Romero and Siebert, 1980, suggest that the inclusion of a legume in the system was similar to a rainfall event in its effect on the quality of the forage consumed by the grazing animals.

Most perennial grass pastures that are established on poor soil types have little or no legume component because of the need for complete weed control prior to establishment. As such, the quality of the forage in these pastures during summer is determined by the management and variety of grasses in the pasture. Some local trial results have suggested that there are large differences in yield and quality of grass pastures (Sanford and Gladman, 2004; Ryan, 2004; Wiley, 2002), however a lack of standardisation of cutting times and nutrition make comparisons between trials invalid. To gain a better understanding of the production and nutritional quality of a range of grasses in the local environment, there appears to be a need for longer term variety trials across the geographic spread of the NAR. This would assess the performance of the grasses across a range of seasonal conditions with standardised sampling times.

Various literature sources based on experiments conducted in tropical environs suggest that phosphorus (Jones and Betteridge, 1994; McLean and Ternouth, 1994) and nitrogen nutrition (Romero and Siebert, 1980; Jones *et al*, 1995) has a significant impact on the grazing behaviour and animal performance of subtropical perennial grasses.

Phosphorus Nutrition

Jones and Betteridge (1994) found differences in the grazing pattern of steers in a tropical pasture consisting of *Stylosanthes* spp., Siratro (*Macroptilium atropurpureum*), Rhodes grass (*Chloris gayana*) and Sabi grass (*Urochloa mosambicensis*) that had been fertilised with superphosphate. On a phosphorus deficient yellow soil (P<5mg/kg), observations of grazing patterns found that the cattle showed significant grazing preference for sites that had received superphosphate. There was no increased preference for sites fertilised with various combinations of sulphur (S), sodium (Na) and calcium (Ca), without phosphorus (P). Although there was significantly higher herbage yield and P concentration in the herbage, with these differences accounted for through covariance there was still significant grazing preference for P fertilised plots. Experience with annual pastures in WA also shows that P fertiliser has a major influence on improving palatability (and

digestibility, animal intake). Lime and K are the other two fertilisers that can significantly improve the palatability of annual pastures (and probably perennials).

The legume component of the pasture studied by Jones and Betteridge (1994) would have benefited greatly from the application of phosphorus and this was not accounted for when describing the selection of fertilised plots by the animals. McLean and Ternouth (1994) covered this gap by identifying the benefits of improving P nutrition on a pasture consisting predominantly of buffel grass (*Cenchrus ciliaris*). Over a 15 month period, cattle grazing plots that received 15kg/ha of P gained an extra 80kg/ha live weight when compared to unfertilised plots. This was attributed to a small increase in dry matter intake and larger increases in P and N intake by the animals in the fertilised plots. In the same trial, P supplementation failed to generate the increased liveweight gains that were observed in the P fertilised plots, indicating the benefits of P fertiliser to animal nutrition extended beyond and increased P intake. The results from this trial contradict that conducted by Jones *et al* (1995) who found that an application of superphosphate had no effect on pasture or animal production. This difference may be attributed to the base fertility of the soils in the experiments. Jones *et al* conducted their experiment on a fertile brigalow soil, and whilst the soil type used by McLean and Ternouth (1994) is not identified, the fact that the pasture was buffel grass indicates the soil type may have been inherently less fertile or 'run down'.

Studies relating to P deficient soils should be directly transferable to grazing environments in the Northern Agricultural Region, as the majority of sites being planted to subtropical perennial grasses are poor sands, often severely deficient in P (McArthur, 1991). The effect of phosphorus nutrition of tropical grasses on grazing patterns has not been studied in Western Australia at this point. It is often quite difficult to isolate the effects of a treatment at the paddock scale due to the mixed nature of pastures in the NAR, especially those that contain annual ryegrass, a high quality forage that is dramatically affected by improved nutrition (Moreschi, 2005).

Nitrogen Nutrition

Several authors have indicated that subtropical perennial grasses show a very marked response in both quantity and quality of dry matter produced when fed a nitrogenous fertilizer (McDowell and Johnson, 2000; Minson, 1973). Dry matter responses have typically been between 11 and 19 kg DM/kg N/ha. Minson (1973), fertilized three subtropical grasses (*Chloris gayana*, *Digitaria decumbens* and *Pennisetum clandestinum*) with two rates of nitrogen (60 and 230 kg N/ha) and then observed changes in feed quality of the grasses through the effects on total nitrogen (crude protein) and dry matter digestibility (energy). The higher rate of nitrogen led to an increase in crude protein (>3.5% increase) and dry matter digestibility (>2% increase) across all species when 5 monthly cuts were averaged. These differences are not as dramatic as some other literature suggests are possible however it is observed that in Minson's work there was no untreated control. McDowell and Johnson (2000) fertilized a *Pennisetum clandestinum* pasture in local conditions (Esperance, W.A.), and found that all rates of nitrogen significantly increased dry matter production and digestibility above an untreated control. Digestibility increases between the 46kgN/ha and 190kgN/ha treatments in McDowell and Johnson's work was of a similar order to that suggested by Minson (1973), however the lowest of the lower rate treatment had 5-10% higher DMD than the control. In this trial dry matter production was around 11.5 kgDM/kgN/ha, indicating that there was no decreased efficiency with rates (up to 190 kg/ha) as the

effect was longer lasting. The residual effect of most treatments in McDowell and Johnson's work had run out by the fourth month of sampling over the summer/autumn period (May) except for residual dry matter production in the highest N rate treatment. This is one of the few local experiments that have been conducted purely on summer growth of the perennial pastures. It is noted that the conditions for that experiment were ideal with 50mm of rain falling within 24hrs of the fertilizer application in January 2000. This, combined with a poor soil type would suggest that the pasture response to the fertilizer was as successful as could be expected (McDowell and Johnson, 2000). Other local work that has been conducted on this subject has tended to be at the farm-scale and has generally involved fertilizer applications in the winter spring period (Wiley and Cahill, 2003: and others), In these situations, although there has been a background level of perennial grass, the major response has been derived from production boosts in annual ryegrass which is known to be highly responsive to applications of nitrogen.

Minson (1973) and Boval *et al* (2002) have suggested that aside from simply increasing the nutritional quality of the grass, improved nitrogen nutrition has the ability to increase voluntary intake of the available forage. This is caused by increasing the nitrogen content of the feed above the threshold level considered limiting to intake (Blaxter and Wilson, 1963). Intake can also be increased through improved nutrition by changing leafiness and flowering habit of the grass (Minson, 1973).

Cutting Frequency Effects on Forage Quality

There is very little data in Western Australia to quantify the effects of rank growth on pasture quality, as most pasture quality analysis does not specify at what growth stage samples were taken. However there has been experimental work conducted by various authors in the eastern states and overseas that have derived relationships between cutting frequency and fodder quality. Milford and Minson (1968) found that regular (monthly) harvesting of various Rhodes grass cultivars stimulated much higher crude protein (15.8% CP) than plots with longer 2, 3 or 4 month regrowth periods (average 9.8% CP). The same relationship was evident for the digestibility of the grass, with monthly cuts across a range of Rhodes grass cultivars averaging 63.2% DMD compared to 55.5% DMD as an average for 2, 3 and 4 month regrowth periods. These results were supported by similar work conducted on a number of grass species that suggested a rapid deterioration in digestibility once the regrowth period extended beyond one month (Minson, 1972). le Roux and Dannhauser (1999) found similar results, albeit with a more extreme rest period cycle. Treatments for a range of sub-tropical perennial grasses in South Africa ranged from a full summer rest (FSR) followed by winter grazing, to resting at the end of January (REJ), also followed by a winter graze. As expected such a long rest period meant that rank growth had reduced pasture quality to sub-optimum levels however it was observed that the FSR treatment had 22% lower crude protein than REJ treatment. The REJ treatment also had the lowest fibre content in the experiment.

In a trial with *Setaria* on poor sand at Bibby Springs, Wiley (2001) found that the frequency of grazing had a much larger affect on Crude Protein than Digestibility. In this trial, conducted in 1994, the setaria with 35 days regrowth had Crude Protein of 7.3 and Digestible Dry Matter (DDM) of 59.2%. For the 200-day regrowth the Crude Protein was almost halved at 3.8%, but DDM had dropped to only 53.0%.

2.3.5 Integration with other pastures

A range of pasture options are available to farmers including the now commonly grown, tagasaste, and lucerne. Each of these perennials has different seasonal patterns of growth. By integrating a range of these types, or 'functional groups', of perennials into farms, it should be possible to increase carrying capacity and year-round animal performance. This could be achieved by strategically moving stock around the farm so that each pasture type is only grazed when it is most productive and of best quality.

A farm at West Gillingara (NAR) has provided an example of how different functional groups of pastures can be integrated into a farming system. A mix of annual legumes and perennial pastures appropriate to soil type has been planted on sections of the farm (Wiley, 2004).

The pastures being trialled on the different soil types are:

Wet flats – Balansa and Strawberry clover, Cadiz serradella, Setaria, Rhodes grass, Kikuyu, Paspalum

Sand over clay – Tagasaste and *Acacia saligna* alleys form a shrub plantation

Alley pasture – Rhodes grass, Setaria, Panic, Cadiz and Yellow serradella

Gravel ridges – Sub clover, Cadiz serradella and lucerne

The year round grazing strategy is based on the different soil types and functional groups of pastures, with the aim of maximising economic and animal performance.

Table 3: Availability of feed from certain locations throughout the year.

	Crop stubbles	Wet flat	Alley pasture	Gravel ridges	Sand over clay
J	x	x			
F	x	x			
M		x	x		
A			x		
M		x	x		
J		x	x		
J		x		x	
A				x	
S				x	x
O			x	x	x
N		x	x		x
D	x	x			

(Adapted from Wiley, 2004)

SECTION 3: POTENTIAL STOCK GROWTH RATES AND ECONOMIC RETURNS

Perennial grasses are only beginning to be developed to their potential in the northern agricultural region of Western Australia. As such, the data available on potential stock growth rates is sparse. Most stock growth rate information is based on on-farm trials.

Examples of the levels of weight gain being achieved on perennial based pasture systems.

- Walkaway, near Geraldton –Northern Agricultural Region.

Cattle are purchased at the break of the season and run through until the export markets are opened. Cattle are run on a Rhodes grass pasture through an intensive rotational grazing system. In 2004, the cattle gained an average of 148 kilograms over 130 days, or 1.14kg/head/day. At a stocking rate of 1.25head/ha, there is a 1.43kg liveweight gain per hectare per day. At a price of \$1.50/kg live weight, the production to 26 October would be worth \$278/ha.

- Mingenew – Northern Agricultural Region

Pastoral cattle are rotational grazed on a mixture of perennial and annual based pastures between the break of the season and the end of the year. In the establishment year, 275kg/ha liveweight was produced using this system at an average growth rate of 0.8-0.9kg/hd/day. At \$1.50/kg liveweight, this equates to \$412 return in the first year.

- Esperance – South-eastern agricultural region

In a trial at Esperance cattle were set-stocked (7-8 DSE/ha) on differing quality perennial grasses on two different soil types. Over 105 days (17th February to 31st May 2004) the average growth weights for the different pastures were 0.6-0.7 kg/hd/day. At a price of \$1.50/kg liveweight, this would equate to a return of \$102/ha in traditionally the worst feed period of the year. An observation of this trial was that the stocking rate was very conservative and animal growth rates could have been maintained at much higher rates. However summer rainfall was unusually high, which allowed more pasture growth than could generally be expected.

These examples give an indication of the type of production that can currently be achieved on perennial based pastures in the Northern Agricultural Region. Because the industry is still in its infancy in the NAR there is still a lot of information to be gleaned from these pastures as they become fully established over a range of seasons. Some trial work has been conducted indicating the positive response of pastures to post-establishment fertiliser (especially nitrogen), however this work needs to be conducted over a broader cross section of rainfall zones and soil types.

SECTION 4: FUTURE WORK

As it can be noted from the review there are many gaps in research in the subtropical grass industry, both locally and abroad, which will dictate the future direction of investigations in WA.

Although most of the agronomy side of the story is becoming quite clear with protocols for species selection, seeding rates, soil type and site preparation already in place, there is constant updating and improvement to be made, as local grower research is investigated with scientific rigour. New species, and especially improved cultivars of existing species are constantly being tested to determine their best fit in the NAR.

The other parts of the agronomy package that are still in early development are the packages for herbicide options and fertilizer requirements. It is clear that a good knockdown prior to sowing is essential for a good establishment, however there has been little investigation into any herbicides that can be used once a perennial stand is established and at what plant growth stages can they be applied. Also with this further herbicide investigation needs to come a study on the potential 'weediness' of the species and what options there are available if this does become a major issue. There are currently very few, if any, herbicides registered for use on subtropical pastures in W.A. and significant testing by local research bodies will be required to generate a safe and reliable herbicide package locally.

Limited trial work has been conducted on the fertilizer requirements of the perennial species. In the trials that have been completed generally there has been huge responses in plant growth and feed quality to nitrogen and phosphorous applications respectively. Though there is still considerable scope for aligning pasture nutrition to animal production with the aims of not only improving production but also profitability. Research into grazing frequency/intensity and the subsequent effects on pasture quality needs to be continued, especially for sheep grazing systems as most research to date has been focused on cattle-based systems. Once again the potential for converting the production gains from this system into increased profitability need to be determined, especially for a predominantly sheep livestock system. The use of economic modelling and benchmarking studies within the Grain and Graze framework will help to quantify these gains, with the aim of achieving the Grain and Graze production and profitability outcomes.

Even though many perennial pastures are grown in a mix with some form of annual legume this area is still widely under studied. Work needs to be carried out on the effect different types of annual legume pasture on the perennial pasture production and also how the rotational grazing systems affect pastures with a mix of annual legumes with perennials.

Future work needs to also be concentrated on the integration of perennials into the whole farming system. For example can an established stand of sub-tropical species be over cropped with a cereal and then regenerate again? How can a perennial pasture phase help with issues of herbicide resistance for the future cropping phase? Much of the previous work has just been focused on how the perennials may benefit the livestock system but there may also be major gains for the cropping phase in mixed farming systems.

So far the areas for future research that have been highlighted have all been associated with production. Probably the most significant knowledge gap in the area of study into perennial species is their effect on the environment. More work needs to be carried out on their impacts on water use - are they reducing the recharge into saline areas? Also on soil health - are the perennials creating an environment that promotes soil organisms to inhabit? There is currently new research being conducted, both within the scope of the Grain and Graze programme and externally, that will allow for a much greater understanding of the effects of subtropical pastures on water use, compared to annual species. This research is being conducted over a range of soil types and will allow us to understand any potential water use benefits of the new species, and in doing so will generate a better understanding of the effects on the nutrient cycle. Medium-high rainfall zones with soils with low water holding capacity are the predominant areas for the adoption of perennial pastures. Therefore, assessing the potential to reduce leaching nutrients into groundwater is an important environmental factor.

It is these questions and the other areas highlighted above that have been largely unanswered in the rapid development of the subtropical perennial grass in WA to date and the Grain and Graze project will endeavour to study these areas.

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