Promising forage options to enhance livestock production in Mediterranean climate agricultural systems

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ABSTRACT

The increasing demand for food, fibre and animal products inevitably requires intensifying agricultural production worldwide. This can present a number of environmental and farming systems challenges in Mediterranean climate areas of the world. Developments of novel strategies, employing ecologically sound intensification practices, are crucial to enhance production in the Mediterranean agropastoral production systems. In this paper, we have discussed forage based systems that improve productivity, profitability, environmental quality and resilience of the farming systems. Key opportunities include better use and integration of diverse genetic resources, new agronomic techniques and the utilization of perennial forage plants that are adapted to land that may not be suited to traditional species. This article has a specific focus on the recent developments on forage based production options for the ecologically sound intensification and enhanced livestock productivity in the low to medium rainfall (< 500 mm/year) Mediterranean agropastoral production systems from the farming context of smallholdings of south Mediterranean countries (West Asia and North Africa; WANA) and large-scale farming systems of southern Australia.

Keywords: Fodder, Grazing systems, Mediterranean climate, Pasture, Ruminants

Introduction

Ecologically sound intensification of agricultural production is critical to meeting increasing consumer demand for crop and animal products without damaging the resource base. Forages present significant potential to ensure agronomic sustainability and mitigate the negative environmental effects of intensified agricultural and animal production (Entz *et al*., 2002; Davis *et al*., 2012). The benefits of forages within farming systems have long been recognized and include production of meat, milk and wool by ruminants, improvement of soil fertility (e.g. nitrogen fixation by legumes), root disease management in cropping systems, increasing biodiversity and risk management through diversified systems (Ates *et al*., 2015; Christiansen *et al*., 2015). Furthermore, feeding systems based on forages contribute to the meeting the consumer preference for higher nutritional value animal products that can be produced with environmentally positive and animal welfare-friendly outcomes (French *et al*., 2000; Hristov *et al.* 2013; Rudel *et al*., 2015).

This paper reports on the recent developments on the forage based livestock production in the south Mediterranean countries and Australia. While WANA and southern Australian may share a similar climate and grow many of the same livestock, crop and forage species, there are significant differences in soils, land tenure and farm management. Briefly, the soils of the two regions differ in that the Mediterranean climate areas of Australia are characterised by much older, weathered and infertile soils, low in nitrogen and phosphorus (Howieson *et al*., 2008, Simpson *et al*., 2011). Land tenure in the Australia is largely freehold while many grazing areas of WANA are communal. Farm size and labour units present the major difference between both regions. In WANA average farm sizes are <10 ha whereas in Mediterranean-climate areas of Australia average farm sizes are >2000 ha and labour averages 1 unit/1000 ha (Bell and Moore, 2012). These differences mean that the key traits for forage improvement may differ between the systems; for example forage conservation in Australia needs to be highly mechanised and sheep are only confined for feeding prior to slaughter.

Across both systems, forage production in areas that are cropped with grains has been declining as the profitability of cereal and oilseed production increases relative to livestock (Australia) and the priority of cereal and food legumes increases (WANA). In addition, animal production based on concentrated feed is becoming increasingly challenged by the competition for grains between humans and livestock and continuous rise in feed prices (Hegarty, 2012; Smith *et al.*, 2013). Conversion of permanent grasslands and natural ecosystems into agricultural land, and intensifying cropping rotations, has been forcing a shift to ruminant production into the marginal areas with subsequent challenges on livestock and plants. For example, use of halophytic plants on saline land has led to some physiological challenges for both the forages and livestock (Masters *et al.*, 2005; Norman *et al.*, 2013). This shift has also been associated with both positive and negative impacts on biodiversity, carbon storage and the hydrological cycle (Norman *et al.*, 2008; Masters *et al.*, 2010; Ates and Louhaichi, 2012).

Despite the longstanding challenges pertinent to the Mediterranean agropastoral regions in WANA and Australia, opportunities exist to increase forage production and better integrate forages in livestock feeding calendars. Development of indigenous forage legumes, better integration of crop and livestock production within conservation agriculture practices, and increased efficiency of livestock production from forages are essential to the agricultural sustainability in the Mediterranean regions. Alternative fodder plants and trees such as cactus and Moringa are emerging valuable sources of forages for livestock particularly in marginal areas.

Forages in the cropping systems of WANA and Australia

In traditional agricultural practice of the southern part of the Mediterranean basin, cereal production is integrated with livestock production, predominantly sheep and goats. Current small ruminant farming is low input and relies extensively on grazing of degraded rangelands, cereal stubbles, weedy fallows, and grain supplementation (Jones, 2000). Cultivated forages comprise of mixtures or monocultures of annual legumes (predominantly *Vicia* spp.) and winter cereals albeit with a low ratio in the cropping system. The annual forage legumes are grown in rotation with cereal crops as a rain fed crop, while alfalfa and berseem clover are grown as irrigated crops. Barley is widely cropped in the WANA region due to its adaptation to drought conditions and uses as food and feed. Barley is a key feed in animal production often grazed in winter season then the regrowth is kept until grain maturity. After harvest, straws, stubbles and grains (partly or entirely) are used in livestock feeding.

In Mediterranean climate areas of southern Australia, legume forages are used to complement cereal production through provision of feed for livestock, a disease break between crops, fixation of soil nitrogen and increasingly an opportunity to reduce weed seedbanks. In ley systems, the forages self-regenerate after a cropping phase of 1-4 years from a seedbank of seeds that remain dormant during the cropping years (Puckeridge and

French, 1983; Taylor, 2005). The forages are usually grazed *in situ* and are rarely conserved as hay or silage. Key species include subterranean clover (*Trifolium subterraneum*) and annual medics but in the last 15 years, innovation has centred on increasing dormancy and reducing the cost of seed though selection of aerial seeding varieties that can be harvested with conventional cereal harvesting equipment (Nutt and Loi, 1999). French *serradella*, yellow *serradella*, *biserrula* and bladder clover are notable new species for these systems (Loi *et al*., 2005). In phase systems, the forages are planted occasionally between long sequences of cereal and oilseed crops (Reeves and Ewing, 1993). Legume forages that may be used in phase systems include French *serradella*, vetches, crimson clover and other annual species that are inexpensive to harvest and have little seed dormancy. Perennials such as alfalfa and chicory are used as phase pastures where rainfall is higher.

Permanent pastures are generally only found in areas that are unsuited to cropping due to soil constraints (acidity, salinity or poor water holding capacity), topography or paddock size and shape (too difficult to sow using large-scale machinery). These pastures are generally diverse and perennial plants provide an opportunity to fill the autumn feed gap. Species include Atriplex and Maireana for saline soils (Masters *et al*., 2007), kikuyu and tagasaste for deep sandy soils (McDowall et al., 2003) and subtropical grasses in areas where winter temperatures do not get too cold (Moore *et al*., 2014). A recent innovation is 'pasture cropping', where crops are opportunistically sown into a perennial grass base (Miller and Badgery, 2009). Alley farming, where crops are planted between alleys of fodder shrubs, occurs in some areas but the changing (increasing) width of cropping machinery and the increased use of GPS guidance tends to limit this practice.

Role of forages in nutritional management of livestock farming and new developments on forage technologies

Annual legumes: Research based on several long-term barley and wheat-based rotation trials at ICARDA has demonstrated the viability of forage legumes in the dryland cropping systems of south Mediterranean region where rainfall is between 250 and 350 mm (Ryan *et al.* 2008; Christiansen et al. 2015). Vicia spp. and Lathyrus spp. are recognized for their potential to enhance the livestock productivity (Rihawi *et al.*, 2010; Ates *et al.*, 2015) and produce extra feed from fallow lands (Larbi *et al.*, 2010; Christiansen *et al.*, 2015). Lamb fattening based on vetch grazing is considered a possible low cost forage based livestock production option for the semi-arid regions of WANA (Rihawi *et al.*, 2010; Ates *et al.*, 2015). The rapid winter and spring growth of Vicia sativa suggest that it could be grown for early grazing when feed shortages are acute in areas with mild winters. With the adoption of Vicia spp. now increasing at the farm level, the prospects for the crop contributing to animal feed supplies are promising (Ates *et al*., 2014). In particular, growing forage legumes under conservation agriculture practices which are expanding in WANA are welcomed by many farmers who are looking for the production of more food and feeds with fewer inputs.

There has been a significant investment in the development of annual legume species for Mediterranean climate areas of Australia. With the exception of forage shrubs and several grass cultivars, all of the sown forages in Australia are based on imported germplasm. Of the annual legumes, it has been estimated that there are 45 cultivars of subterranean clover, 40 annual medic cultivars and a number of cultivars of serradella, biserrula, bladder clover, gland clover, balansa clover, Persian clover, crimson clover and arrow leaf clover (Nichols *et al.*, 2007). As a general rule, new cultivars are developed to fill niches that are not serviced by existing material. For example, Messina is a new annual legume being developed for waterlogged saline soils (Nichols *et al.*, 2012). There is also an opportunity to develop a broader suite of biserrula cultivars to reduce methane emissions from sheep and assist in weed management (Revell and Thomas, 2004, Ghamkar *et al.*, 2013).

A recent development is novel sowing methods that utilise the natural breakdown of seed dormancy to reduce the costs of pasture establishment. Hard seeded forage legumes are normally established using scarified seed, a process which removes this type of seed dormancy. The high germination seed is sown generally after opening rains and weed control with the loss of winter forage production. Twin sowing involves sowing dormant seed either with a crop or after crop emergence (Loi *et al.*, 2008). Summer sowing involves the planting of the dormant seed in late summer/early autumn (Loi and Nutt, 2010). Both systems rely on seed harvested on farm at a low relative cost, and sufficient breakdown of dormancy over the summer/autumn period. The legumes establish at the start of the season and can dramatically increase the amount of legume biomass produced compared to normal establishment methods (Loi *et al.*, 2008). Effective management of weed competition is a critical component of these methods. They are particularly useful for the introduction of *serradella* species where the seed in tightly bound within woody pods that are difficult to remove and allow seed scarification.

The Fodder shrubs and trees: The difficulty to produce conserved fodder in less favourable, arid areas receiving less than 250 mm annual rainfall often results in feed shortages. In these marginally dry areas of southern Mediterranean, fodder shrubs and cactus present significant potential to reduce the feed gap and reliance on grain supplementation (Ben Salem and Smith, 2008; Ben Salem *et al.*, 2010). Characterized by a remarkable tolerance to drought conditions, high water use efficiency, a rapid dissemination and growth, a high biomass yield and multipurpose uses, cactus is a promising forage species that can promote livestock sector in dry areas and improve farmer's incomes. Another lesser-known plant, qualified as "Miracle tree", *Moringa oleifera* is grown intensively in plantations and produces over 100 tons of fresh foliage/ha with a protein content of 18-25 percent which has a biological value comparable with soybean (Foidl *et al.*, 2001). The leaves of *M. oleifera* are also a good source for macro- and micronutrients, â-carotene, vitamin C, calcium, potassium and a number of antioxidants (Makkar *et al.*, 2007; Fuglie, 2001; Siddhuraju and Becker, 2003).

A combination of shrubs or cactus and herbaceous species (legumes and/or grasses) that can be produced in alley-cropping system is considered an excellent diet for sheep (Ben Salem *et al.*, 2010). Cactus cladodes are high in soluble carbohydrates, calcium and â-carotene (Ben Salem and Abidi, 2009) but they are low in fibre and crude protein (Stintzing and Carle, 2005). Therefore, supplementation of fibre and protein sources is recommended when feeding cactus to ruminants. In their review paper, Ben Salem *et al.* (2010) explained the complementary role of cactus and *Atriplex nummularia* L. The foliage of the later halophyte species is high in crude protein and fibre but is low in energy. In addition, the high water content of cactus cladodes would dilute the high salt in *A. nummularia* making the association of these two forage species important for the improvement of ruminants raised in harsh environments.

In Australia there has been a major focus on improving the nutritional value of *Atriplex nummularia.* Very few forage species tolerate the combined stresses of aridity and salinity in the saline valley floors of the low to medium rainfall zone of southern Australia. *A. nummularia* has been planted by farmers on land that is too saline for cereal crops, to provide green feed during autumn when the majority of plants in the landscape are dead. It is a valuable source of crude protein, sulphur, vitamin E and minerals within meat and wool production systems (Norman *et al*., 2004; 2013). However, it can have low to moderate digestible energy concentrations and high salt, sulphur and oxalate levels. Whole farm economic modelling indicated that improving the energy value of old man saltbush would substantially increase farm profitability (O'Connell *et al*., 2006; Monjardino, 2010). Sensitivity analyses predicted that improving shrub digestibility by 10% would increase profits by three times the increment associated with increasing biomass production by 10%, or reducing the cost of establishment by 10% (O'Connell *et al*., 2006). In 2015, a cultivar with 20% higher digestibility and higher palatability was commercialised.

Forages for extra nutritional benefits: Condensed tannins (CT), also known as proanthocyanidins, are widespread in dicotyledonous species and occur infrequently in graminacae. They are common in the foliage of a wide range of Mediterranean shrubs and trees and some herbaceous forage legume like sulla (*Hedysarum coronarium*) and sainfoin (*Onobrychis viciifolia*). CT bind to proteins in the rumen, reduce protein degradation and when dietary crude protein (CP) concentrations exceed animal requirements, these effects can improve performance. Ben Salem *et al*. (2005) reported that the association of small amount of tannins-containing shrub legumes, i.e. *Acacia cyanophylla* Lindl, to soybean meal supplementing an oat hay-based diet increased the growth rate of lambs. Similarly appropriate use of saponin-containing feedstuffs could stimulate ruminal fermentation, thus improves livestock production. Recently, Ben Salem *et al.* (submitted) reported that the incorporation of small amount of fenugreek (*Trigonella foenum-graecum*) seeds that contain saponins in the concentrate increased by 30% the growth rate of lambs receiving oat hay.

Furthermore, these phytochemicals and some others like essential oils proved efficient in reducing methanogenisis when administered at certain levels to ruminants (Martin *et al*., 2010). Thus, better use of forages in livestock feeding in the sense of smart integration of phytochemicals-containing forage species in ruminants' diets may have significant potential to reduce methane emission caused by livestock. Identifying the threshold of the level of tannin-containing forage species to tackle the in situ protein protection (i.e. increase the proportion of bypass protein) and their anthelmintic activity (i.e. reduce gastrointestinal parasite) is a novel research topic being investigated by some laboratories. Other plants with alternative methane reduction pathways are being investigated in Australia, including the shrub species *Eremophila glabra* (Li *et al*., 2014).

Conclusions and future directions

An integrated participatory approach should be adopted to uncover a variety of options for management of a degraded natural resource base and in order to foster sustainable production systems within Mediterranean forage systems. In order to build upon the considerable research conducted on forages, provide technical and economic assessment of forages in cropping systems, and to promote technology transfer at the farm and community level. There is need for forage species and cultivars that are inexpensive and simple to establish, and resistant to biotic and abiotic stresses such as disease, drought and salinity. Ability to outcompete weeds in low tillage systems where herbicide resistance is a problem would also be advantageous.

In Australia, there is a need to better understand the value of forages as break crops and their role in reducing weed populations for subsequent cereal and brassica crops. There is a clear opportunity to improve the nutritional value of pastures (to increase feeding value and reduce methane emissions from ruminants) and to continue to fill nutrient gaps through use of perennials (shrubs, grasses and legumes) and forage conservation. Underutilised technologies such as the establishment methods 'twin sowing' and 'summer sowing' and crop grazing in winter need to be demonstrated to industry at a commercial scale to improve adoption. Decreasing funding for forage research and development offers a major threat to future innovation.

In WANA, *Vicia* and *Lathyrus* spp. are high biomass producing forage legumes that are adapted to dryland conditions of south Mediterranean. Utilizing different cultivars of *Vicia* and *Lathyrus* with low anti-nutritional factors, high protein content and biomass under abiotic stress environments in semi-arid parts of Mediterranean region may boost the livestock based livelihood of resource poor farmers. Long term studies are needed to compare the profitability of forage based systems to monocultures, without disregarding the value forages offer in terms of ecological services and environmental benefits. Better integration of drought and salt-tolerant forages and shrubs in feeding calendars would improve livestock performances and alleviate the impact of biophysical constraints in the Mediterranean agropastoral production systems. Government policies should also promote forage cultivation by offering incentives for forage production.

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