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SUSTAINABLE PASTURE PRODUCTION:

PRINCIPLES OF SUSTAINABLE PASTURE PRODUCTION

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Abstract: The pasture legume seedbank has been identified as the major factor contributing to long-term sustainable annual pasture production in both the cereal-livestock (cropping) zones and the higher-rainfall (grazing) zones of temperate Australia. The critical factors leading to the decline of legume-based pastures in both zones include excessive grazing by sheep in summer and autumn (when large amounts of medic pod and clover burr may be ingested), sowing legume seed too deep for reasonable emergence, inadequate control of depth of tillage and inadequate control of insect pests. Stocking rate continues to be the dominant factor in controlling pasture utilisation but it also affects pasture production and botanical composition. Changes in botanical composition are compatible with sustainable pasture production.

INTRODUCTION

The temperate pastures of southern Australia comprise four major pasture zones, *viz.*

- the arid and semi-arid rangelands,
- the cereal-livestock (cropping) zone,
- the higher-rainfall (grazing) zone, and
- a small, but important, irrigated pasture zone.

Within the grazing industries these zones are complementary. There is usually a one-way movement of store animals and breeding stock from the rangelands to the other zones.

This interzonal complementarity takes account of both biological/ecological factors and recognises that the grazing animal affects the availability, quality and survival of the pasture and the pasture affects the production and survival of the grazing animal.

The major effects of the grazing animal are treading, defoliation, recycling of nutrients and dispersal of seed. All four of these effects may influence yield, botanical composition and persistence of pasture species (Carter, 1968; 1990b). Thus sustainable pasture production depends on the complex soil-plant-animal interrelations of particular districts within the four major pasture zones. With decreasing rainfall, the problems of both survival and regeneration of pasture increases (Carter, 1968).

In the cropping areas the main indicators of potential productivity and sustainability of pastures are the seedbank of annual pasture legumes and pasture cover during the growing season (helping production) and the cover of the dry pasture residues in summer (preventing erosion). In the higher-rainfall grazing areas the annual pasture legume seedbank is most important but so, too, is the content of perennial grasses. Of course, perennial pasture legumes (*eg.* white clover and strawberry clover) may be most important where these can persist. Again, percentage pasture cover is a most important indicator of productivity. While botanical composition may change in response to stocking rates the percentage overlapping cover and percentage bare ground as determined by the Levy Point Quadrat (Levy and Maddern, 1933) are excellent indicators of the potential productivity and sustainability of the pasture.

This paper will concentrate on identifying and managing the critical factors related to long term,sustainable pasture production in the above-mentioned cereal-livestock (cropping) zone and higher-rainfall grazing zone of southern Australia.

THE CEREAL-LIVESTOCK ZONE

Good pastures in the ley-farming system of the cereal belt should be legume dominant. These legume pastures in the cereal-pasture rotation can minimise the incidence of cereal root disease and maximise nitrogen fixation thereby improving wheat and barley yields and profitability.

Research by E.D. Carter with technical assistance and some post-graduate students over the past 20 years involving monitoring of pasture legumes in the cereal belt, has shown that typically 80-90% of farms have insufficient legume seed reserves following a cropping sequence to regenerate a satisfactory legume-based pasture. Some 15 reasons have been identified (modified from Carter, 1981b) as contributing to the demise of pasture legumes in the cereal belt as follows:

(1) Inadequate reduction of cereal straw and dry pasture residues;

(2) Reduced spraying to control red-legged earth mite and lucerne flea;

(3) Reduced application of superphosphate to pasture;

(4) Spread of Sitona weevil;

(5) Increased cropping intensity and consequent increased grazing pressure;

(6) Poor grazing management for weed control in pastures

(7) Poor fodder conservation practices: mowing too late and too low

(8) Increased use of herbicides in the cropping phase of the rotation;

(9) Reduced undersowing of medics and clovers into cereal crops;

(10) Sowing of medics and clovers too deeply also deep tillage;

(11) Rapid spread of pasture aphids (SAA, BGA,CPA);

(12) Increased use of nitrogenous fertilisers;

(13) Wrong choice of medic and clover species, cultivars and mixtures;

(14) Poor seasons and droughts; and

(15) Apathy and despondency concerning the value of medics and clovers.

However, there are some good pastures in all districts and our aim is to transfer the technology of proven techniques and assist farmers to monitor the density and subsequent productivity of legume pastures as a guide to management decisions. Our observations supported by research indicate that the most common reasons for failure of legume pastures in the cereal belt are as follows:

Inadequate legume seed reserves resulting from the cumulative effects of varying aspects of mismanagement (Table1).

Inadequate reduction of cereal straw and dry pasture residues. Not only does straw cause problems for tillage and sowing, but it directly and indirectly influences emergence of medics and clovers following the opening rains (Quigley and Carter, 1989).

Inadequate control of summer-autumn grazing of medic pods and clover burrs especially on hard-setting soils where sheep may consume 1 t/ha of medic seed or 2/3 t/ha of sub clover seed in a few weeks (Carter, 1981a; de Koning and Carter, 1989).

Inadequate control of depth of tillage which buries excessive amounts of pasture legume seed too deep for emergence in the naturally-regenerating pasture following a cropping sequence (Carter *et al.*, 1987; Quigley, Carter and Knowles, 1987; Fulwood and Carter, 1989).

Inadequate control of sowing depth especially on heavier-textured soils (Carter and Challis, 1987).

Inadequate control of insect pests especially red-legged earth mite and lucerne flea at break of season.

Inadequate control of weedy grasses and broad-leaved weeds by grazing or spraying. Studies at Kapunda, Tarlee and Turretfield Research Centre have shown the benefits of grass control for legume seed production, sheep production and reduction of cereal disease (Carter, 1990a; Little *et al.*, 1992; Inwood *et al.*, 1992)

Inadequate recognition of the impact of haymaking on legume seed reserves (Carter *et al.*, 1988)

Improving wheat belt pastures depends on improving the legume component. All the indications are that if legume density is maintained at a high level then most other problems will decline or disappear.

In considering technology transfer to farmers, research and extension workers must be aware of the justifiable attitudes of farmers who are unlikely to accept advice on improving wheat belt pastures unless the adoption of that advice will:

- make money, or
- save money, or
- save work.

As always, the improvement of existing pastures must aim for maximum benefit at minimum cost.

Table 1: Distribution of sites with corresponding total medic seed reserve, emergence, hard seed reserve and pasture survey data in the Mallala district, 1981(Source: Carter, 1982; Carter *et al.*, 1982)

Number of sites	Seed reserve March 1981 (kg/ha)	Seed reserve March 1981 ($\#/m^2$)	Cumulative emergence[A] ($plants/m^2$)	Hard seed reserve September 1981 (kg/ha)	Hard seed reserve September 1981 ($\#/m^2$)	Pasture survey[B] Medic (%)	Pasture survey[B] B/ground (%)
14	9	394	35	6	250	8.5	38
3	33	871	80	25	735	31.6	38
5	71	2914	215	48	2030	35.1	29
6	136	4745	387	100	3644	53.7	13
3	244	9409	475	139	5572	58.6	10
4	321	11625	985	218	7991	72.3	6

Notes: [A]Until 30 July, 1981; [B]Levy point quadrat data collected 18-24 August, 1981.

When the legume seedbank is poor it is not necessarily a case for expensive pasture renovation. It can be cheaper and easier to use a grass herbicide like Fusilade, to improve the competitive ability of the legume and increase legume seed production as was the case at Tarlee in 1989 and Turretfield Research Centre in 1990 where 350 ml/ha Fusilade, improved the quality of both greenfeed and dry feed, decreased grass-seed problems in Merino lambs and improved both wool value and lamb value.

In terms of pasture renovation and re-establishment, there is a great need for further research on cost-effective ways of establishment. Much more research is needed (replicated in time and space) on the role of seed placement in dry versus wet seed-beds, the role of compaction (using press wheels, *etc.*) to ensure better seed-soil contact for moisture exchange and germination. In view of the poor farm commodity prices it is time to re-look in the wetter districts at the possible scope for under-sowing legumes in cereal crops as a means of saving money (reduction of sowing rates can minimise risk). Furthermore, the scope for 'sowing' medic pods in marginal rainfall areas needs critical evaluation.

CRITICAL MANAGEMENT ISSUES THROUGHOUT THE YEAR

(1) Straw management is vital for seedbed preparation, breakdown of hard seed in pasture legumes and regeneration of pastures.

(2) Summer-autumn grazing pressure on medic pods and clover burrs can be vital for maintaining seed reserves (Tables 2, 3 and 4). Sheep first select the largest pods or burrs containing the most seed and largest seed. As grazing continues the smallest seed survives and this has the least ability to produce a viable seedling following burial during tillage for a crop. There is a case for lot feeding (followed later by deferred grazing) to protect both the seed supplies and the soil (Carter *et al.*, 1993).

(3) Monitoring legume seed reserves by the ring-watering technique can take the guess-work out of deciding whether a paddock needs extra legume seed sown following a cropping sequence. (Carter and Porter, 1992).

(4) After the break of season pasture residues and cereal straws may seriously depress emergence of pasture legume seedlings (Table 5). Insect pest control is essential to protect newly-emerged pasture legumes.

(5) Tillage for cereal crops can markedly reduce legume seed reserves by burying seed too deep for seedling regeneration (Table 6). Shallow scarifying buries least seed; however, an occasional deeper ripping may be necessary on some soils. Also, too much pasture seed is being sown too deeply for successful establishment.

(6) Hard grazing in winter by sheep can greatly reduce weed problems and optimise seed production of clovers and medics provided grazing pressure is

Table 2: Survival of medic seed following ingestion of a pure-pod diet by sheep (Source: Carter, 1980).

	M.truncatula (cv. Jemalong)	*M.scutellata* (Commercial)	*M. littoralis* (cv. Harbinger)
Pods eaten (g/day)	757	755	555
Seeds eaten (#/day)	85540	18000	65480
Seed output (#/day)	1530	354	876
Seed output/intake (%)	1.79	1.97	1.34

Table 3: The components of mature medic pasture (kgDM/ha) in a field experiment at the Waite Institute during autumn 1979 (Source: Carter, 1981a).

Component	Cumulative grazing period (days) 0	7	14	21	28	35	42	49	56
Total pasture	4573	4216	3758	3124	2674	2088	1891	1190	816
Medic pods	2154	2087	1746	1490	1256	831	841	408	275
Medic herbage	2293	2100	1997	1607	1407	1241	1034	771	538
Green weeds	126	29	15	27	11	16	16	11	3

Table 4: Data on medic pods and seeds before ingestion by grazing sheep in the Waite Institute field experiment during autumn 1979 (Source: Carter, 1981a).

Component	Cumulative grazing period (days) 0	7	14	21	28	35	42	49	56
Pods (#/m^2)	4167	3866	3111	3040	2601	1812	1878	917	619
Pod weight(mg)	54.5	54.7	54.1	50.4	49.8	47.6	47.1	46.2	46.9
Seeds/pod	6.86	6.82	6.35	6.43	6.30	5.74	5.55	5.13	4.53
Viable seeds^A	23715	22936	17497	16541	14916	9142	9475	4153	2652
Seed weight(mg)	2.87	2.76	2.76	2.79	2 .71	2.68	2.72	2.68	2.54

Notes: ^{A}viable seeds/m2 based on sum of permeable and impermeable seed.

Table 5: Effects of Weeah barley straw concentration on emergence of Paraggio barrel medic seedlings above the straw, 10 days after sowing (Source: P.E. Quigley, Waite Agricultural Research Institute).

Straw Concentration (t/ha)	Emergence (#/pot)^A	Emergence (%)^B
0	28.2	77.1
2	23.3	63.7
4	19.7	53.9
6	8.8	24.0
8	4.3	11.8

Notes: ^{A}40 seeds sown per pot; mean of 6 replicates; ^{B}Percentage emergence with correction for seed germinability.

Table 6: Effects of tillage in 1986 on medic in 1987 (Source: Carter *et al.*, 1987).

	Mouldboard ploughed 1986	Scarified 1986
March 1987		
Total seed reserves (kg/ha) 0-5 cm soil	63	450
April 1987		
Emergence (plants/m^2)	178	1173
June 1987		
Hard seed reserves (kg/ha)		
0-5 cm soi	132	310
5-15 cm soil	172	31
15 cm soil	7	3

Table 7: Botanical composition of pasture and seed production, Tarlee 1989 (Source: Carter, 1990).

	Legume	Grass	Other spp.
Unsprayed			
Botanical composition (%)	15	85	trace
Seed production (kg/ha)	121	342	33
Sprayed with Fusilade,			
Botanical composition (%)	88	10	2
Seed production (kg/ha)	269	5	2

reduced when flowering starts.

(7) While grazing can greatly assist in weed control, grass herbicides have an important role in controlling botanical composition to greatly improve the legume percentage and legume seed production (Table 7). The benefits of such spraying may persist for two or three years which spreads the cost.

(8) Haymaking, especially when early and not mowing too low has no effect on seed production of subterranean clover but greatly reduces seed production by medics.

HIGHER RAINFALL GRAZING ZONE

While the objective in the cereal belt is to have pure legume crops or pasture stands preceding cereal crops, in the higher-rainfall areas our objective is for balanced grass-legume pastures.Many of the constraints to pasture production in the ley-farming areas also apply in the higher-rainfall grazing areas where cropping to oats, barley, lupins, *etc.* is mainly related to pasture renovation, or to help with cash flow.

The problems of maintaining an adequate legume seedbank are fewer in the higher-rainfall areas than where cropping is more frequent but the botanical composition of the pasture frequently reflects the legume seedbank. Some of the older oestrogenic cultivars of subterranean clover are excellent seed producers and dominate the pasture. This can be reflected in yield of crops after the pasture (Table 8). However, in this case it is impossible to separate the contributing effects of cereal disease control and levels of soil nitrogen.

Clearly, it is important to know the potential yield of nutritious pasture in any agro-ecological zone. But this information is sadly lacking in most areas of southern Australia. As yield of pasture is the main

Table 8: Effect of pasture composition and /or clover cultivar on the yield of a following barley crop at North Bannister, Western Australia (Source: D.A. Nicholas, WA Dept. of Agriculture).

Cultivar	Pasture composition Oct. 1978		Barley yield 1979
	Clover (%)	Grass & weeds (%)	(kg/ha)
Dinninup	98	2	3409
Dwalganup	77	23	2713
Seaton Park	56	44	2641
Daliak	63	37	2622
Uniwager	60	40	2509
Woogenellup	61	39	2432
Geraldton	63	37	2401
Midland B	58	42	2267

determinant of potential livestock production it is high time that this information be obtained and documented. In 1968 there were 161 stocking rate experiments in Australia but only three of these had worth-while information on pasture production (Carter, 1968). I doubt whether this deplorable lack of information has improved in the past 25 years. At present, too much research money is used to fund "magic" and not enough to fund pasture management studies.

Livestock production from sown pasture depends on the product of YxUxE where Y is yield of pasture or forage crop, U is the percentage utilisation and E is efficiency of conversion of herbage into meat, milk and wool. In general terms we can increase livestock production in the higher -rainfall areas by expanding the grazing areas, increasing pasture and forage crop production per unit area (yield), increasing stocking rate (utilisation) and increasing production per head (efficiency).

There is no merit in increasing the production of pasture unless there are sufficient grazing animals to efficiently convert that extra pasture into meat, wool or milk. This involves a consideration of the optimal level of utilisation of the pasture and the choice of appropriate stocking rates. Of all grazing management factors, stocking rate has the greatest impact but optimal financial returns will normally occur at less than maximum potential stocking rates.

There are no simple recipes for making money at farming. If so, you would not be here-nor would I. Certainly, grazed livestock enterprises are more complex than crops.

Crop: Usually have a single harvest and single marketable product *(eg.* grain).

Pasture: Have continuous harvest by the animal. The pasture affects the animal and the animal affects the pasture. In considering stocking rates or any other grazing aspect we must deal with the soil-plant -animal complex ecosystem.

Examples of the impact of stocking rate on pasture production and utilisation, also greasy wool production are given in Tables 9 and 10 (Carter, 1977). Medium to medium-high stocking rates sustain better pastures, better sheep, more wool and more profit.

Stocking rate not only affects pasture production and livestock production but also has dramatic effects on botanical composition. Tables 11 and 12 summarise some of the results from the Waite Institute (Carter 1967, *et seq.*) Cluster clover and other small-seeded clovers increase on all heavily-grazed, higher-rainfall Mediterranean climatic environments in the world associated with sheep, goats and other herbivorous animals. Our recent studies at the Waite Institute have shown that, whereas larger legume seeds have an advantage in being able to emerge form greater depths in the soil, under prolonged grazing, especially at heavy stocking rates, small legume seeds escape damage through chewing by the grazing animal.

Table 9: Mean values for pasture production and utilisation also greasy wool production at Waite Institute

Stocking rate (Sheep/ha)	Pasture grown (kg DM/ha)	Pasture utilised[A] (kg DM/ha)	Wool grown (kg/ha)
7.4	9804	4133	53
12.4	11168	6815	86
14.8	11616	7904	104
17.3	12308	8761	116
22.2	11715	10678	130

Note: [A]Pasture crude utilisation values at shearing time in mid-March.

Table 10: Mean indices of greasy wool production in relation to pasture production pasture utilisation and April-November rainfall

Stocking rate	Wool grown kg/ha/1000 kg DM	Wool grown kg/ha/1000 kg CU	Wool grown kg/ha/100 mm rain
7.4	5.45	13.1	10.0
12.4	7.85	12.8	16.3
14.8	9.21	13.4	19.7
17.3	9.65	13.5	21.8
22.2	11.34	12.3	24.3

Table 11: The effects of stocking rate on seed production of cluster clover, the quantity of sheep faeces, total seed content and the amount of cluster clover and winter grass seed present in faeces during March after five growing seasons at the Waite Agricultural Research Institute (Source: Carter (1977); Carter and Lake (1985).

Stocking rate	Cluster clover seed	Faecal pellets	Total faecal seeds	Seed numbers and germination percentage of seeds in 40g samples of faecal pellets			
				Cluster clover		Winter grass	
(Sheep/ha)	(kg/ha)	(kg/ha)	(#/m^2)	(#)	(%)	(#)	(%)
7.4	<1	306	1	1	0	0	-
12.4	<1	634	20	11	82	0	-
14.8	1	754	22	14	93	0	-
17.3	16	948	321	127	96	0	-
22.2	439	1334	14451	4171	95	1006	15

Note: [A]Faecal pellets that accumulated during the previous summer

Table 12: The effects of stocking rate on the patterns of seedling emergence from sheep droppings collected in March and subsequent botanical composition in May after 5 years continuous grazing at the Waite Institute (Source: Carter, 1987).

	Seedlings emerging from 10g sheep faeces covered with sand						
Stocking rate (Sheep/ha)	Sub clover	Barley grass	Sour sob	Cape weed	Cluster clover	Winter grass	Total plants
7.4	1	2	-	2	1	0	6
14.8	0	0	-	12	3	0	15
22.2	2	0	-	0	217	48	267
	Percentage botanical composition in May						
Stocking rate (Sheep/ha)	Sub clover	Barley grass	Sour sob	Cape weed	Cluster clover	Winter grass	Total plants
7.4	23.4	74.1	0.8	1.4	0.0	0.0	0.3
14.8	5.8	6.1	trace	88.0	0.0	0.0	0.1
22.2	12.2	0.0	16.6	20.8	24.6	25.8	0.0

Hence small-seeded, hard-seeded legumes have a 50% to 60% survival after ingestion by sheep in contrast to subterranean clover and medics that have a survival following ingestion of generally less than 5%.

Grazing livestock can dramatically influence botanical composition in the short-term and long-term Control of weeds by livestock is more sustainable than using herbicides. However, both methods are needed for weed control.

CONCLUSIONS

In optimising the benefits from improved management of the pasture-livestock enterprise in both the cereal belt and higher-rainfall areas it is essential to consider the total farm operation. Pasture legumes will continue to be of vital importance in the sustainable pasture production in both the cropping and grazing zones in the foreseeable future; however, perennial grasses have an important role in the higher-rainfall areas of temperate Australia to confer some stability to botanical composition and to help prevent a rising water table in some areas. Sadly there is a great deal of information available that is not reaching the farmer and at meetings such as this we strive to increase the transfer of information and technology to assist primary producers.

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