LUCERNE - A FRESH LOOK

R.G. Purves, R.B. Wynn-Williams

DSIR Crop Research Division
Private Bag
Christchurch

ABSTRACT

The 1988-89 drought on the east coast of New Zealand highlighted the need for alternative forage species. The area of lucerne (*Medicago sativa* L.) in New Zealand has declined over the past 15 years but the drought has renewed interest in lucerne as an alternative forage, especially in low rainfall areas.

Lucerne's advantages and disadvantages are evaluated with emphasis on dryland farming in New Zealand.

***Additional Keywords:** Lucerne, alfalfa,* Medicago sativa, *drought.*

INTRODUCTION

Lucerne (*Medicago sativa* L.) is often referred to as the "Queen of the Forages". Globally some 32 million ha of the crop is grown but in New Zealand the area is small and declining. Barnes *et al.* (1988) attributes the success of lucerne in the USA, where 13 million ha are grown, to its agronomic adaptability, its importance as a source of protein from biological nitrogen fixation and its energy efficiency as a crop. Lucerne's adaptability makes it particularly useful in dry environments.

As a result of the 1988-89 drought on the east coast of New Zealand, the climatic predictions for these areas and the poor performance of ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) pastures in drought prone areas, there is new interest in growing lucerne.

The purpose of this paper is to review the role of lucerne as a dryland pasture species. Lucerne's advantages and disadvantages are discussed.

CHANGES IN AREA OF LUCERNE PRODUCTION

The area of lucerne in New Zealand increased constantly until 1976 when 220,000 ha was grown (Table 1). Since then the area has declined to 83,700 ha (Department of Statistics, June 1988). The decrease in area was initially large with annual declines of 20,000 ha each year from 1978 to 1981 but since then the rate of decline has decreased. No change in area occurred between 1987 and 1988 suggesting that the decline in area has ceased. Area has declined in all the major statistical regions, the decline ranging from 77 % in Canterbury to Otago with 35 %. The decline in area also occurred in most counties. Vincent County was an exception, where the area remained static because of the dependence on lucerne for winter hay supplements.

Table 1: Area of lucerne 1976 and 1988.

	1976	1988
New Zealand	219,816	83,697
North Island	33,171	15,875
South Island	186,645	67,822
Canterbury	112,263	25,569
Otago	52,869	34,398
Ashburton County	27,659	4,643
Vincent	13,908	14,114

The increase in lucerne area prior to 1975 was due to an extension "push" for lucerne including an establishment subsidy in some areas, as a result of a series of dry summers during the 1970s (Dunbier *et al.*, 1982). During this time lucerne's advantage over pasture was greatest. Adult lucerne was resistant to insect pests, especially grass grub (*Costelytra zelandica*), a major problem at that time. The subsequent decrease in lucerne area was due to a number of direct and indirect factors.

Indirect factors reduce the need to grow lucerne, including changes in management, especially "all grass" wintering, increased use of irrigation and the closure of dehydration plants. For example, from 1978 to 1981

Canterbury farmers increased irrigation on pastures by 66 % to 98,000 ha (Department of Statistics). As will be discussed further, the production advantage of lucerne over pasture decreases under irrigation and the advantage is greatest on drought prone soils. Increased use of irrigation may also allow land traditionally growing lucerne to be used for cropping. Indirectly, irrigation has thus contributed to the decline in the area of lucerne.

Direct factors include those that effect production, persistence and the economics of lucerne. According to Dunbier *et al.* (1982) the introduction or recognition of a number of pests and diseases exacerbated by a series of seasons with above average rainfall were major factors causing loss of farmer confidence in lucerne. Poor grazing management and high establishment costs have also been contributing factors. Pests, diseases and poor management have decreased stand life and led to increased production costs. In Canterbury where the area of irrigated lucerne has increased, persistence of lucerne has decreased (Moss, 1986). Since 1982 new pest problems have emerged or spread into new areas. This accelerated the decline of lucerne and made cultivar choice difficult.

THE ADVANTAGES OF LUCERNE

Lucerne is usually compared with traditional, mainly ryegrass/white clover pasture and lucerne's advantage may reflect weaknesses in these pastures.

Dry matter production: Research data demonstrating lucerne's dry matter production was reviewed by Douglas (1986). On unirrigated sites lucerne yielded 53 % more herbage than pasture (mean of 32 sites) with a range of 0 % to 180 %. The magnitude of the advantage is dependent on climate, soil type and management of the crop. Greatest production has been recorded on rich, moisture retentive soils where yields of over 20 t/ha dry matter have been measured. However, on these soils lucerne's advantage is not as great as those with free draining soils of low water holding capacity. Under dryland conditions droughts can cause variations in lucerne's yield but they are still markedly superior than those of other legumes under these conditions. Greenwood (1979) concluded for areas where annual rainfall are 350 mm, 550 mm and 750 mm lucerne's advantage over pasture was 100 %, 50 % and 25 % respectively.

Lucerne's advantage over pasture is reduced with increasing rainfall or by the use of irrigation. In a trial in South Canterbury, lucerne's yield advantage over ryegrass/white clover decreased from a nine year average of 51 % to 19 % during the wet growing seasons from 1974 to 1976-77 (McLeod, unpub.data). Irrigation has had a similar effect in trials at 5 sites in mid-Canterbury (Hayman & McBride, 1984). Lucerne's advantage over pasture decreased from a mean of 32 % to 13 % with irrigation (Table 2).
The magnitude of the change at each site was dependent on the water holding capacities of each soil.

Year to year production of lucerne is less variable than that of conventional pasture. Hayman & McBride (1984) showed that lucerne yields tend to vary less with application of water. A similar response could be expected in wet seasons. The reliability of lucerne is

Table 2. **Response of lucerne and pasture to irrigation of 5 sites in Mid-Canterbury (adapted from Hayman & McBride 1984).**

Site and soil type		Non Irrigated yield t/ha		Irrigated yield t/ha		Mean response as % non-irrigated yield	
		Lucerne	Pasture	Lucerne	Pasture	Lucerne	Pasture
1	Lismore	6.5	4.1 (37)	7.3	6.4 (12)	44	56
2	Eyre	7.7	5.5 (29)	11.8	10.5 (11)	53	91
3	Eyre	9.6	7.0 (29)	11.5	10.8 (6)	20	54
4	Wakanui	10.6	7.1 (33)	14.0	10.6 (24)	32	49
5	Wakanui	12.0	8.4 (30)	14.6	12.6 (14)	22	31

( ) % yield advantage of lucerne over pasture greatest on drought prone soils because its deep rootedness allows it access to a greater resource of water than that available to ryegrass/white clover pasture. It is therefore less influenced by short term droughts. Physical or chemical characteristics that prevent deep rooting may decrease this advantage and increase variability in production.

Lucerne has the advantage of higher summer production. White (1982) showed that on shallow stony soils in Canterbury, lucerne's dry matter production declines from October but the rate of decline is not as great as that of pasture and, consequently, it produces more herbage from September until March. Some alternative pasture species such as tall fescue (*Festuca arundinacea*) and prairie grass (*Bromus willdenowi*) have higher production than perennial ryegrass in areas of prolonged moisture deficits or light soils (Anderson *et al.*, 1982; Fraser, 1985). However, no comparisons have yet been made with lucerne.

Feed quality and animal production: It has been found that lucerne is better than conventional pastures for finishing lambs irrespective of the season. Ulyatt (1978) and Fraser (pers.comm.) compared the feeding value of lucerne with other pasture species. Only on a pure white clover sward were greater daily liveweight gains achieved (Table 3a and 3b).

Table 3a: The comparative feed values of some pasture species grown in New Zealand for sheep liveweight gain (Ulyatt, 1978).

Species	Relative liveweight gain
High endophyte ryegrass*	100
Browntop	100
Timothy	129
Lotus pedunculatus	143
Short rotation ryegrasses	148
Italian ryegrass	160
Lucerne	170
White clover	186

Liveweight gains of over 300 g/day are common but a summary of trials measuring lamb growth rates on lucerne showed that growth rates drop from spring to summer (Douglas, 1986). However, the animal production remained greater than that achievable on pasture. Mace & Sherlock (1975) reported a 200 % increase in lamb meat per hectare over local pastures for a summer period. High levels of lamb production were achieved on a dryland lucerne farmlet at Winchmore, mid-Canterbury, where at a stocking rate of 15 ewes/ha, meat production of 237 kg/ha (range 211 - 304 kg) was achieved over 11 years (Knight, 1986). This compared favourably with the high producing irrigated farmlet at Winchmore where meat production averaged 315 kg/ha (range 263 - 338 kg) over a 5 year period (Moss, 1986). Heavy lambs were produced on the lucerne farmlet with a mean carcass weight of 14.4 kg.

Table 3b: Growth rates of sheep fed *ad lib.* on some pasture species grown in New Zealand (Fraser, pers.comm.)

Species	Growth Rate (g/day)
High endophyte ryegrass*	155
Rangi rape	165
Non endophyte ryegrass*	225
'Grasslands Wana' cocksfoot	225
'Grasslands Matua' prairie grass	230
'Grasslands Roa' tall fescue	266
'Grasslands Puna' chicory	300
Wairau Lucerne	308
'Grasslands Huia' white clover	321

* Summer grazed compared with other species which were spring grazed.

Conserved feed: Lucerne can make high quality hay. In drought prone areas with cold winters, like Central Otago, lucerne has remained important as a supplementary feed. Lucerne hay has approximately twice the crude protein and slightly higher digestible energy levels than meadow hay (Ulyatt *et al.*, 1980). Greater meat production has been achieved using lucerne hay as a supplement than with meadow hay (Scott *et al.*, 1980).

Resistance to pasture pests: Lucerne has often been seen as an alternative pasture species in areas where grass grub attack causes considerable damage to ryegrass/white clover pastures. Adult lucerne plants resist attack from grass-grub, porina (*Wiseana* spp.) and

Argentine stem-weevil (*Listronotus bonariensis*) which can be major problems, especially in dryland pastures. Pasture recovery from the 1988-89 drought in the South Island was severely limited by these insect pests which appear to thrive under dry conditions (French, 1989). Argentine stem weevil is a serious problem in drought years and where low endophyte ryegrasses are grown persistence may be limited to 2 years (Fraser, pers.comm.).

THE DISADVANTAGES OF GROWING LUCERNE

Seasonality of production: A major limitation to the amount of lucerne that can be integrated onto a farm is lack of production during the late autumn, winter and early spring. Many pasture species grow more than lucerne during this period and production in autumn can be carried into the winter whereas late summer lucerne growth can only be carried forward in areas free of severe frosts. However, lucerne cultivars are now available that will grow more in late autumn and early spring but according to Lucas (1984) the greater use of root reserves made by cool season active cultivars reduces their spring production. Although unmeasured this may have a detrimental effect on their long term performance, when cool season active cultivars are grown in cold climates.

Utilisation of production: Digestibility of lucerne declines with increasing maturity. The digestibility of leaves remains constant but that of stems declines. With a reduction in the leaf/stem ratio this results in an overall reduction in digestibility. The decline in liveweight gain of lambs from spring to summer and sutumn follows the pattern of decline in digestibility of stems at the same time (Fletcher, 1976). Foliar fungal diseases which result in leaf drop, especially during autumn, produce a similar effect.

To obtain high animal production from grazed lucerne, especially if mature lucerne, utilisation must be low. To finish lambs it has been suggested that lambs be used to graze leaves and shoot tips and the less digestible stems be used for other stock (Christian *et al.*, 1970). Feed of high digestibility can be obtained over summer and autumn by grazing lucerne when it is immature (Fletcher, 1976). This however may be detrimental to subsequent growth and stand life. Jagusch *et al.* (1970) suggested that lambs should be weaned onto lucerne as early as possible to allow them to utilise the highly palatable and nutritious lucerne leaf.

The introduction of new cultivars which are more upright and have thicker stems than the traditional cultivar Wairau has made good utilisation and hay making more difficult. These difficulties can be overcome by grazing or cutting at the 10 % bud stage which is generally prior to the "hardening" of stems.

Grazing management: Lucerne is not tolerant of either frequent or over grazing. A grazing duration of 14 days with a spelling period of 42 days is a general recommendation. Poor grazing management can result in loss of production and reduced plant survival (O'Conner, 1970). During early spring and other periods of feed shortage, grazing management of lucerne is often poor.

Management of lucerne to optimise animal production while maintaining stand vigour is more exacting than management of ryegrass/white clover but many of the "new" pasture species require a similar high level of management.

Animal health problems: Bloat is an occasional problem when feeding sheep and cattle on lucerne although Croy & Weeda (1974) reported fewer difficulties grazing cattle on lucerne than with ryegrass/white clover pasture. Red gut (Jagusch *et al.*, 1976) can cause sheep death when lush lucerne is fed particularly in the spring. In early weaning experiments reported by Jagusch *et al.* (1976, 1976a), 1 - 3 % of lambs died as a result of red gut but this could be reduced by feeding weedy lucerne or using meadow hay supplements (Jagusch *et al.*, 1976b). Lucerne/grass mixtures, weedy lucerne and pastures can be used to prevent death of ewes fed predominantly on lucerne in the spring (McLeod, 1976; Brosnan, 1982).

Coumestans which accumulate in lucerne as a response to foliar fungal infection (Purves *et al.*, 1981) and aphids (Kain & Biggs, 1980) result in oestrongenic activity which depress ovulation rates and decrease multiple births in ewes flushed and mated on lucerne (Smith *et al.*, 1980). Fungal leaf spots tend to build up in the autumn corresponding to the mating of ewes. In drought prone area lucerne could be used as a flushing feed if coumestan levels can be controlled. Young regrowth which is low on coumestans especially in cultivars resistant to foliar diseases may be used to flush ewes (Purves *et al.*, 1981).

Establishment costs: Farmers perceive that lucerne is an expensive crop to establish. Seed costs, especially of imported cultivars, have been high when compared with ryegrass/white clover seed costs. The costs of some recommended seed mixes are listed in Table 4.

Table 4: Seed costs of lucerne compared with selected pasture mixes.

Pasture Type	Total Seed Cost $/ha[1]
CRD Otaio lucerne (10)	100.00
'Grasslands Nui'[2] ryegrass (20) + 'G. Pitau' w/c (3)	49.50
'Roa' tall fescue (20) + 'Pitau' white clover (3)	155.50
'Roa' tall fescue (15) + 'Maru' phalaris (1.5) + 'Pitau' white clover (3)	140.25
'Matua' prairie grass (30) + 'Pitau' white clover (3)	94.50

( ) Seed rate kg/ha. [1] Estimate based on 1st Generation prices quoted 10 August 1989. [2] All pasture cultivars are DSIR Grasslands varieties.

Although there are variations on the possible pasture mixes available, clearly the seed cost of lucerne is more expensive than ryegrass/white clover but is similar to mixtures using species currently seen as alternatives to ryegrass/white clover pastures in dryland areas.

Costs of establishing lucerne can be reduced if lower seeding rates are used. The seeding rates used by farmers ranges from 4 - 20 kg/ha with an average 11.5 kg/ha (Wynn-Williams, 1982). Seeding rates should be related to the sowing date and seed conditions. With spring sowing and under good conditions 2.5 kg/ha of viable seed can be sufficient to result in a stand of adequate density, however, with autumn sowing under marginal conditions even 10 kg/ha may not result in a stand of adequate density (Wynn-Williams, 1982). Hume & Fraser (1985) concluded that optimum plant density can be achieved by a sowing rate of 5 - 6 kg/ha. Clearly seeding rates used by farmers are too high but to reduce them will require greater attention to seed bed preparation and time of sowing.

Cover crops can be used to recover establishment costs in the first year of production. Janson (1978) pointed out that the economic advantages of using cover crops were greater on better soils where the gross margins of barley undersown with lucerne were 4 - 5 times greater than lucerne alone.

Maintenance costs: Lucerne is considered an expensive crop to maintain because of the cost of fertilisers, pesticides and herbicides. Reducing fertiliser costs is not compatible with extra production. Savings may be made by applying fertilisers after consideration of a soil test. Pesticide costs have decreased with the decline in insect pest problems in lucerne. Herbicide costs can be reduced if factors causing weed invasion are corrected. As a stand ages the number of plants decline and this thinning is accelerated by either pests, diseases or mismanagement. Herbicides can be used to control weeds and maintain hay value but where stands have already thinned controlling weeds will contribute little to restoring the stand. In these situations it is recommended that weeds be sprayed out and production boosted by oversowing with a grass.

Disease and pest problems: Since the 1970's diseases and pests have had a major effect on the persistence of lucerne. Major disease problems are listed in Table 5.

The severity of insect pests, particularly aphids, has declined over the last 10 years most probably due to biological control and through stand management. Sitona weevil *(Sitona discoideus)* a severe problem which effects lucerne production in dryland areas with light soils, is now being controlled by the parasitic wasp *(Microtonus aethiopoides)*. It is believed that sitona populations have been reduced below the threshold level where significant damage is caused (S.L. Goldson, pers.comm.). Insecticide controls previously recommended (Goldson & Muscroft-Taylor, 1988) should not be necessary unless biological control strategies break down.

The incidence of diseases has not been surveyed in the 1980s. It may be speculated from the decline in lucerne area that their distributions and severity have not changed.

Stem nematode *(Ditylenchus dipsaci)* a widespread problem of lucerne in the South Island, has been increasing in incidence. A survey of lucerne stands in Central Otago during 1988 found that many stands were infected (Purves, unpublished data). As experienced in North Otago and Canterbury the movement of stem nematode in Central Otago has been rapid and its effect on stand persistence severe.

Table 5: Major pests and diseases of lucerne in New Zealand.

Pest/Disease	Severity	Distribution
Bacterial wilt	Severe	New Zealand
Blue-green aphid	Light-moderate	New Zealand
Pea aphid	Light-moderate	New Zealand
Verticillium wilt	Moderate	New Zealand, especially North Island
Crown rot	Light-moderate	New Zealand
Stem nematode	Severe	Localised but severe in many parts of the South Island
Phytophthora root-rot	Severe	Localised areas with wet soils and irrigated soils
Leaf diseases	Light-moderate	New Zealand, especially humid areas
Sitona weevil	Severe	Light soils and young stands.

There are now lucerne cultivars available with resistance to the major pest and disease problems but no one cultivar has resistance to all the major problems. The key to good stand performance is to choose the correct cultivar. This can be achieved by diagnosing disease or pest problems that have affected older stands. If old infected stands are not available to provide this information assume the worst and in the South Island choose cultivars resistant to stem nematode, bacterial wilt *(Corynebacterium insidiosum)* and possibly aphids. In the North Island consider cultivars resistant to bacterial wilt, Verticillium wilt *(Verticillium albo-atrum)* and leaf diseases. The major impact pests and diseases have had on lucerne production in New Zealand makes it critical that in the future cultivars with the right disease and pest resistances are sown if satisfactory results are to be achieved.

THE ROLE OF LUCERNE IN FARMING

Having discussed lucerne's advantages and disadvantages, where does lucerne fit into farming as a pasture species?

Traditionally lucerne has been grown as specialist stands for either finishing lambs or for hay. For these purposes lucerne has been particularly important in dryland areas on the east coast of the South Island where low and erratic summer rainfall and cold winters, especially in central areas, severely limit pasture growth. The 1988-89 drought on the east coast of New Zealand has highlighted the vulnerability of farmers using only ryegrass/white clover pastures and also the need to have conserved hay in the shed. In these areas lucerne's traditional role remains important.

There has been much discussion on the proportion of lucerne that can be grown on a farm given the constraints of lack of cool season growth and extra management difficulties. Where high production is consistently achieved using ryegrass/white clover only 15 % of a farm in lucerne may be required for finishing lambs (Jagusch *et al.*, 1980). White (1982) considered that the percentage on a farm in lucerne should relate to the productive advantage of lucerne over pasture. A 30 % production advantage was necessary to show economic benefits. Where the advantage was great up to 60 % of a farm could profitably be in lucerne despite increases in management difficulties. Brosnan (1982) successfully integrated lucerne at 64 % of a 570 ha farm in the drought prone Hakataramea Valley with a resultant increase in carrying capacity from 1,100 to 3,000 stock units. Wool production was increased from 4,000 to 18,000 kg and considerable income was made from the selling of hay.

The integration of lucerne into a farm will increase the amount of summer production available and to utilise this production increases in stocking rates are necessary. This creates difficulties in winter and early spring when deficits occur. Different management strategies can be used to overcome the problem of early spring deficits as a result of low lucerne production at this time. Brosnan (1982) profitability utilised this excess in production by selling hay and maintaining stocking rates at a level which could be managed in winter and early spring. Later lambing can be used to match animal requirements with lucerne's growth pattern (White, 1982) but late lambing can create difficulties in finishing lambs (Fraser & Vartha, 1979). Some Central Otago farmers have overcome this deficit by grazing lambs and ewes on lucerne at an early stage and accepting lower annual production (Talbot, 1982). This strategy to overcome early deficits is not advocated because of the long term detrimental effect this management is likely to have on stand life.

Winter/early spring feed deficits can be overcome by integrating lucerne with other grass species. Ryegrasses, prairie grass, phalaris and tall fescue all have higher growth rates during early spring. Sowing other species with lucerne has been used to increase winter and early spring production (Field, 1980). This approach has been unsuccessful as the grass species have displaced lucerne (Fraser, 1983). It is therefore recommended that lucerne should only be established as a pure sward. Warren (1975) used ryegrass pastures for the purpose of early spring feed on a farmlet consistingof 62 % lucerne which had a carrying capacity 50 % above the district average. Using lucerne and pasture in this way is seen as the best approach to integrating lucerne onto a farm.

CONCLUSION

Lucerne has an important role to play as a pasture species especially in dryland areas where drought and insect pests have resulted in the poor persistence of ryegrass/white clover pasture and caused stock health problems on animals grazing them. Resistance to the major pests and disease problems through the use of resistant cultivars and an increased knowledge of the management required to obtain high performance from lucerne there is considerable scope for increased use of lucerne as an alternative forage species.

REFERENCES

Anderson, L.B., Brock, J.L., Boyd, A.F., Harris, A.J. & Ryan, D.L. 1982. "Grassland Roa" tall fescue: herbage dry matter production and quality under mowing. *New Zealand Journal of Experimental Agriculture 10,* 275-280.

Barnes, D.K., Goplen, B.P. & Baylor, J.E. 1988. Highlights in the USA and Canada. In: *Alfalfa and alfalfa improvement.* (ed. A.A. Hanson, D.K. Barnes & R.P. Hill Jr.). pp 1-22. Agronomy No. 29 Madison, Wisconson.

Brosnan, M. 1982. Lucerne for grazing - A farmer's view. In: *Lucerne for the 80's* (ed. R.B. Wynn-Williams). *Agronomy Society of N.Z. Special Publication No. 1,* 107-109.

Christian, K.R., Jones, D.B. & Freer, M. 1970. Digestibility and chemical composition of fractions of lucerne during spring and summer. *Journal of Agricultural Science, Cambridge 75,* 213-222.

Croy, B.G. & Weeda, W.C. 1974. Beef production on pasture and lucerne. *Proceedings of the New Zealand Grassland Association 36,* 73-79.

Douglas, J.A. 1986. The production and utilisation of lucerne in New Zealand. *Grass and Forage Science 41,* 81-127.

Dunbier, M.W., Wynn-Williams, R.B. & Burnett, P.A. 1982. Lucerne for the 70's. In: *Lucerne for the 80's.* (ed. R.B. Wynn-Williams. *Agronomy Society of New Zealand Special Publication No. 1,* 3-7.

Field, T.R.O. 1980. Can we manipulate the annual pattern of pasture growth? *Proceedings of the New Zealand Grassland Association 41,* 80-88.

Fletcher, L.R. 1976. Effect of season and regrowth period on the *in vitro* digestibility of irrigated lucerne in Canterbury. *New Zealand Journal of Experimental Agriculture 4,* 469-472.

Fraser, T.J. 1983. Irrigated lucerne with perennial grasses and Tama ryegrass for prime lamb production. *New Zealand Journal of Experimental Agriculture 11,* 297-301.

Fraser, T.J. 1985. Role of Matua prairie grass in an all-grass system for prime lamb production. *Proceedings of the New Zealand Grasslands Association 46,* 50-55.

Fraser, T.J. & Vartha, E.H. 1979. Experience with lucerne-grass systems for sheep production. *Proceedings of the New Zealand Grasslands Association 41,* 50-55.

French, R.A. 1989. Insect numbers hamper recovery of pasture after drought. In: *Christchurch Press,* July 14, 1989, 20.

Goldson, S.L. & Muscroft-Taylor, K.E. 1988. Inter-seasonal variation in *Sitona discoideus* Gyllenhal (Coleoptera : Curculionidae) larval damage to lucerne in Canterbury and the economics of insecticidal control. *New Zealand Journal of Agricultural Research 31,* 339-346.

Greenwood, P.B. 1979. Lucerne growing in Otago. *Farm Production and Practice Aglink, 233.* Ministry of Agriculture and Fisheries, Wellington.

Hayman, J.M. & McBride, S.D. 1984. The response of pasture and lucerne to irrigation. *Winchmore Irrigation Research Station, Ministry of Agriculture and Fisheries Technical Report. No. 17.*

Hume, D.E. & Fraser, T.J. 1985. Establishing and managing recent cultivars in arable dryland pastures. In *Using herbage cultivars.* (ed. R.E. Burgess & J.L. Brock.) *Grassland Research and Practice Series No 3, New Zealand Grassland Association.*

Jagusch, K.T., Clarke, V.R. & Jay, N.P. 1970. Lamb production from animals weaned at three to five weeks of age on to lucerne. *New Zealand Journal of Agricultural Research 13,* 808-814.

Jagusch, K.T., Grumbrell, R.C. & Dellow, D.C. 1976. Red gut in lamb lucerne grazing trials at Lincoln. *Proceedings of the New Zealand Society of Animal Production 36*, 190-197.

Jagusch, K.T., Gumbrell, R.C., Modley, M.C. & Jay, N.P. 1976a. Effect on growth of early weaning lambs on to pure lucerne stands. *New Zealand Journal of Experimental Agriculture 5*, 15-18.

Jagusch, K.T., Gumbrell, R.C., Mobley, M.C. & Jay, N.P. 1976b. Effect of salt blocks and roughage as supplements to grazing lucerne at growth rate of lambs and incidence of deaths from "red gut". *New Zealand Journal of Experimental Agriculture 5*, 19-22.

Jagusch, K.T., Rattray, P.V., Smith, J.F., Lynch, R., Oliver, T. & Brunswick, L.F.C. 1980. The strategic use of lucerne pastures as feed for sheep. *Proceedings of the Agronomy Society of New Zealand 10*, 19-22.

Janson, C.G. 1978. Raising the profitability of first-year lucerne. *New Zealand Journal of Agriculture 136, (5)*, 25-29.

Kain, W.M. & Biggs, D.R. 1980. Effect of pea aphid and blue-green aphid on coumestrol levels in herbage of lucerne. *New Zealand Journal of Agricultural Research 23*, 563-568.

Knight, T.L. 1986. Sheep production on dryland lucerne. *Proceedings of the New Zealand Grassland Association 48*, 207-210.

Lucas, W.J. 1984. Cool-season management of a winter-active lucerne cultivar. M.Appl.Sc. Thesis, Lincoln College, University of Canterbury.

McLeod, C.C. 1976. Lucerne on South Canterbury downlands 3. Management practices. *New Zealand Journal of Agriculture 132, (1)*, 44-45.

Mace, M.J. & Sherlock, R.R. 1975. Lamb fattening with lucerne on pumice lands. *New Zealand Journal of Agriculture 131, (1)*, 30-31.

Moss, R.A. 1986. Production on an old irrigated pasture. *Proceedings of the New Zealand Grassland Association 48*, 215-218.

O'Connor, K.F., 1970. Influence of grazing management factors on herbage and animal production from lucerne pastures.*Proceedings of the New Zealand Grassland Association 32*, 108-116.

Purves, R.G., Hood, N.D. & Dunbier, M.W. 1981. The effect of cutting management and fungicide application on coumestan levels in three lucerne cultivars. *Proceedings of the New Zelanad Weed and Pest Control Society 34*, 25-28.

Scott, J.D.J., Lamont, N., Smeaton, D.C. & Hudson, S.J. 1980. Sheep and cattle nutrition. *Agricultural Research Division Bulletin*. Ministry of Agriculture and Fisheries, Wellington.

Smith, J.F., Jagusch, K.T., Brunswick, L.F.C. & McGowan, L.T. 1980. The effect of lucerne feeding on ovulation rate in ewes. *Proceedings of the New Zealand Society of Animal Production 40*, 44-49.

Talbot, E.A. 1982. Grazing management in practice - Otago. In *Lucerne for the 80's*. (ed. R.B. Wynn-Williams. *Agronomy Society of New Zealand Special Publication 1*, 119-122.

Ulyatt, M.J. 1978. Aspects of feeding value of pastures. *Proceedings of the Agronomy Society of New Zealand 8*, 119-122.

Ulyatt, M.J., Fennessy, P.F., Rattray, P.V. & Jagusch, K.T. 1980. The nutritive value of supplements. In *Supplementary feeding. A guide to the production and feeding of supplements for sheep and cattle in New Zealand. New Zealand Society of Animal Production Occasional Publication No.7*, 157-184.

Warren, I.F. 1975. Lucerne on the South Canterbury downlands. 1. The Adair demonstration unit. *New Zealand Journal of Agriculture 131 (6)*, 21-25.