Paper 3
LUCERNE ESTABLISHMENT — OVERSOWING AND OVERDRILLING

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INTRODUCTION

The potential usefulness of lucerne as a pasture legume in the dry hill and high country has long been recognised. In the semi-arid zone there are large areas of soils with naturally high pH, base saturation and fertility, which are well suited to lucerne (Douglas, 1970b). There are also extensive areas of more acid soils in the sub-humid zone, where lucerne has agronomic advantages over clovers (Iverson, 1965; Clare *et al.,* 1981).

Cockayne (1922b) had only limited success establishing lucerne by oversowing, but it was not until much later that experimentation was initiated to overcome the major technical problems of introducing lucerne into such difficult environments (Ludecke, 1962; Nixon, 1971; Douglas, 1970b; White, 1970a). Douglas (1970a) reported that the lucerne established from Cockayne's sowings flourished until opened in 1930, when severe overgrazing suppressed the lucerne. It was not until grazing was controlled in the 50's that the lucerne increased again. These early sowings emphasised the ability of lucerne to survive and produce in this environment. The problem was the initial establishment.

Thoughout this review, oversowing is taken to refer to broadcasting seed on the surface, and overdrilling refers to drilling the seed into uncultivated ground. Either process may involve the use of herbicides to reduce competition if necessary, depending on the condition of the existing sward.

SOWING METHOD

Wherever it is physically possible to overdrill or practice minimum tillage, these should be the preferred methods of sowing. The improvement in establishment and greater reliability, that results from seed being placed in the soil, has been noted in many environments (Ludecke, 1962; Watkin and Vickery, 1965; Janson and White, 1971a; Clifford, 1975; Dowling and Sykes, 1975).

The conditions under which overdrilling is superior to minimum cultivation have not been well defined, but an important factor in favour of overdrilling is the minimised risk of wind and water erosion. White (1970b) mentions the farmer use of single discing to reduce competition in North Canterbury hill-country before drilling in lucerne. However, with adequate chemical weed control, it seems that in most situations, overdrilling will give as good or better establishment and production than either conventional cultivation or minimum tillage (Clare and Matthews, 1969; Atkinson, 1976; Smith and Stiefel, 1978). Although in one instance at Wairakei, Atkinson (1976) noted a yield depression from overdrilling, and suggested that herbicide residues may be implicated.

The principles of minimum tillage are implicit in the development of the N.Z.A.E.I. 'roto-drill' (Dunbar *et al.,* 1980). Lucerne and grass establishment with the roto-drill has been better than overdrilling at the drier sites tested, although clover establishment was not improved and at wetter sites the roto-drill was not superior. This suggests that reduction in competition, rather than cultivation *per se,* is the dominant effect. Since Smith and Stiefel (1978) have shown higher soil moisture in overdrilled soil compared to minimum tillage it seems likely that similar or better results than the roto-drill might well be achieved by reducing competition with a suitable herbicidal spray before overdrilling. This latter system could handle a greater range of soil conditions and has the advantage of narrower coulter spacings, giving a more even stand, thus reducing inter-plant competition and erosion.

Under good conditions overdrilling can be successful in spite of the machinery used. However, farmer acceptance has been hampered by unreliability under dry conditions. To improve reliability, a machine evaluation and design programme led to the development of a 'chisel-opener' (Baker, 1981). This forms an inverted T shaped groove, torn or shattered beneath the surface (Baker, 1976; Baker *et* *al.*, 1979). This shape reduced loss of in-groove humidity compared to triple disc or hoe-type opener (Choudhary and Baker, 1981); this factor being correlated with the better performance of the chisel-opener in dry conditions, when compared to the more usual V or U shaped groove. Baker (1979) has emphasized that differences between opener designs have been as high as 14 fold, and differences in the order of 1.6-5 fold are common. Even with a commonly-used opener, a bar cover harrow (Baker, 1970), increased establishment by up to 14 fold. Thus many failures of overdrilling in the past, may have been due to deficiencies in the machines used, rather than an inherent deficiency of the concept. Further improvements in machine design will allow more confident adoption of the overdrilling technique in the future (Baker, 1979).

USE OF LIME

White (1973) suggested that soils with a pH of 5.8-6.0 or higher were required for oversowing lucerne. A lime pellet is often sufficient to give good nodulation on such soils, without the need for expensive aerial applications of lime. The use of relatively small (420-1250 kg/ha) dressings of lime for oversowing has been investigated in a number of experiments (Fig. 1). The large responses to lime, when soil pH is below 5.7-5.8, suggest that the use of lime would be critical for success on more acid soils. Although some work has shown a lime x lime coat interaction (Table 3) other experiments did not record any such interaction. This suggests that the 35% response in establishment recorded at higher pH is independent of lime-coating effects and can be obtained from amounts of lime as low as 360 kg/ha (Douglas, 1974). The economics of the use of such small amounts need further investigation, but it could be an attractive means of increasing establishment. Better definition of the minimum quantities required to achieve this response would greatly assist this economic evaluation.

Where ground contour allows overdrilling, the economics of using small amounts of lime are much more favourable, in that lime, drilled in close proximity to the seed, is considerably more effective than lime broadcast on the surface (Parle, 1967; White, 1967; 1970a and b). For example at pH 5.6 drilled lime at low rates was as effective in promoting nodulation as high rates broadcast (Table 1).

TABLE 1. Lime effects on nodulation and growth of Wairau in an acid soil (pH 5.6).

Treatment	Lime rate (t/ha)	Nodulated plants/plot	Yield (g D.M./plant)
No lime	0	10.9b	13
Lime in drill row	0.6	17.4a	25
Lime broadcast	5.0	21.4a	35

After: White (1970a)

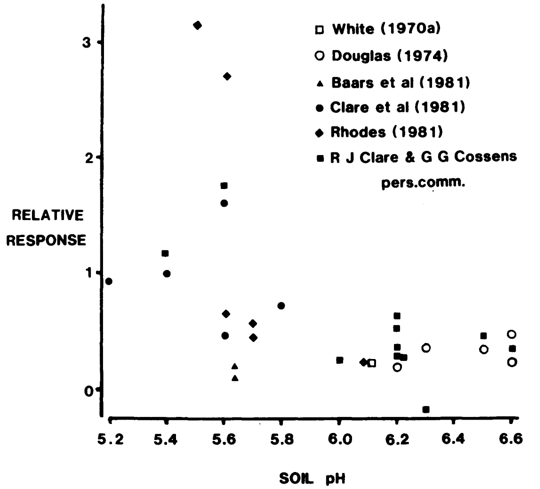

Figure 1: Establishment responses to low lime rates (420-1250 kg/ha) relative to no lime (=0) on soils of varying pH.

SWARD TREATMENT

The existing sward has two distinct effects, acting both as a protective cover and as a competitor for water, light and nutrients. Thus, decisions on the appropriate sward treatment need to weigh up the interacting factors involved.

Cover

A number of studies in dry environments have shown the beneficial effects of cover on early seedling establishment (Dowling *et al.*, 1971; Janson and White, 1971a; Musgrave, 1976).

More detailed studies in dry environments have shown that final germination is usually obtained after a number of separate germinations in response to falls of rain, and that viability of seeds that remain on the surface for long periods is drastically reduced (Campbell and Swain, 1973a). However, the presence of cover has been shown to promote early germination (Janson and White, 1971a) and to play a major role in reducing the losses of seedlings from desiccation (Campbell and Swain, 1973a). These benefits mainly accrue from the increased relative humidity in the vicinity of the seed (Dowling *et al.*, 1971; Evans and Young, 1970). However, cover has also been shown to reduce temperature extremes (Evans and Young, 1970) frost lift (During *et al.*, 1963), the rate at which the soil surface strength increases in dry periods following rain (Campbell and Swain, 1973b) and to increase surface heterogeneity (Dowling *et al.*, 1971; Campbell and Swain, 1973b). All these factors have been shown to aid early seedling establishment.

Competition

Lucerne has been shown to be more sensitive to competition at establishment than other commonly oversown legumes (Campbell, 1968; 1974a). Thus the use of a herbicide to reduce competition during the establishment year has been shown to be essential for successful establishment of lucerne by oversowing or overdrilling. The only exception to this has been the sparse native pastures of North and Central Otago, which are of low nitrogen status and low competitive ability.

Where danthonia (*Notodanthonia* spp.) is present as a major component of the sward, a strong allelopathic interaction on legume establishment can occur (Parle, 1964; Janson and White, 1971b). Nodule formation is either completely suppressed, or the nodules that form are small and appear ineffective (Beggs, 1962; Janson and White, 1971a). The toxic component responsible is produced in the danthonia roots but is readily leached, so that in areas where annual rainfall is above 650-750mm, legume nodulation is not a problem in the presence of danthonia (J.N. Parle, pers. comm.). In drier environments it is necessary to kill the danthonia either with 1.4 kg/ha paraquat (White, 1970a), a 2,2-DPA/amitrole mixture (Janson and White, 1971a) or glyphosate (Moore, 1979). Merely checking danthonia with 0.56 kg/ha paraquat gave severely reduced lucerne nodulation (Janson and White, 1971a).

HERBICIDES

Without exception, the most successful herbicide treatments have been those which have given suppression of the resident vegetation, not only at the early seedling establishment phase, but also during the first summer. The lucerne seedling is very vulnerable to competition in periods of drought stress if it has not had time for full tap root development. The choice of herbicide in individual situations must be based on the cheapest herbicide or combination of herbicides, that will give the long-term suppression required. The main chemicals which have been used are:

Paraquat:

A quick-acting contact herbicide which is inactivated by soil contact but is very poorly translocated. Thus a single paraquat spray can only be used where the existing sward is of low vigour and/or contains few perennial species of rhizomatous or deep-rooted habit, which are little effected by paraquat. Examples of such use include the native red grass pastures of New South Wales (Campbell, 1968), a fertilized annual clover/grass based sward in North Otago (Musgrave, 1976), a danthonia sward in North Canterbury (White, 1970a) and a browntop sward at Wairakei (Atkinson, 1976).

Paraquat has also often been used as a pre-sowing spray to clean up germinating annuals and uncontrolled perennials following an earlier spray - usually a residual herbicide such as 2,2-DPA, on browntop/danthonia swards in Marlborough (Nixon, 1971; Rhodes, 1977; Moore, 1979); 2,2-DPA/amitrole on ryegrass/white clover swards in North Auckland (Atkinson, 1976) and vigorous improved pasture in Marlborough (Rhodes, 1981); paraquat and dicamba on ryegrass/white clover swards in North Auckland (Atkinson, 1976), and after an earlier paraquat spray on low vigour browntop swards in the pumice country (B. Koller, pers. comm.). Small losses (c.2-6%) of germinating oversown seed have been attributed to the effects of residual paraquat retained on the existing sward (Campbell and Swain, 1973a; Baars *et al.*, 1981), but a 7-14 day interval between spraying and germination eliminates the problem (Warboys and Ledson, 1965).

2,2-DPA:

A slow-acting herbicide, effective primarily against grass species. It has only been successfully used alone prior to oversowing or overdrilling, when there is a low proportion of broadleaved weeds or clovers in the sward, such as on a pure native grass sward in New South Wales (Campbell, 1968; 1974a; 1976). However, 2,2-DPA has been successfully used in a wide range of situations when combined with herbicides such as amitrole, which are more active against broad-leaved species. Examples include the danthonia-based swards of North Canterbury (Janson and White, 1971a) and Marlborough (Nixon, 1971; Rhodes, 1977; 1981), a paspalum-based sward of Raglan (Atkinson, 1976), native pasture of New South Wales (Dowling *et al.*, 1971; Campbell, 1976). The use of 2,4-D (Dowling *et al.*, 1971) and simazine (Campbell, 1974a) have not been as effective as the use of amitrole.

2,2-DPA has a prolonged residual effect, and a spell of 30-40 days prior to seeding is generally observed but 15-20 days could be sufficient (M.H. Campbell, pers. comm.). A shorter spell could be particularly useful to avoid a pre-sowing spray of paraquat in some situations.

Glyphosate:

A foliar-acting herbicide that is translocated within the plant from treated herbage and is thus capable of killing both grasses and broad-leaved species and hard-to-kill rhizomatous and deep-rooted weeds. It is inactivated by contact with the soil. Glyphosate has many advantages for use with oversowing or overdrilling, but there are some problems with its use, besides its cost. Spray contact with seed has not generally been considered a problem (Moore, 1979), however, Campbell (1974b) has shown that glyphosate applied to legume seed substantially reduced establishment, although grasses were little affected. The interaction between the damaging effects and the short-term reduction in competition from the spray is illustrated in Table 2. For lucerne establishment from oversowing the spelling period for glyphosate is approximately 20 days (Campbell, 1976). Glyphosate can also require the use of a light rate of dicamba to control clover growth in spring (Moore, 1979).

The use of glyphosate when overdrilling lucerne gave good control of couch and yarrow (Butler and Meeklah, 1979) and also gave good results when used as an alternative

Unfortunately lime-coating was not sufficient to ensure nodulation under very adverse conditions, although later work did suggest that a more absorbent coating (diatomaceous earth) may give more consistent responses (Musgrave, 1975).

A number of attempts have been made to promote early seedling vigour by the use of fertilizer coats or pellets. Hirota (1972) reported that up to 5%of NPK fertilizer promoted "germination", although more detailed measurements have shown that growth responses to fertilizer do not occur until at least 5 days after imbibition (McWilliam *et al.,* 1970). Scott and Archie (1978) reported that use of slow-release fertilizer coats gave approximately two-fold responses to elemental sulphur, and smaller responses to additions of superphosphate or Gafsa phosphate. They calculated that a 100% elemental sulphur coat should be sufficient to provide the sulphur requirements for the production of 2 t DM/ha, thus allowing the possibility of oversowing lucerne in a semi-arid environment without fertilizer in the first year, a practice not recommended in the absence of a fertilizer coat (Musgrave, 1980).

TIME OF SOWING

In arable situations lucerne is generally sown in October — November, although Wynn-Williams (Paper 2) suggests that September sowings are preferable, except on moisture-retentive soils, where somewhat later sowings are as good. Later sowings tend to be practiced to allow more time for spring weed control cultivations, although Janson (1972) has shown that the desired result of a cleaner stand is not necessarily achieved. It is an important attribute of overdrilling that the chemicals used are designed to suppress weed competition, so that spring-sown lucerne should be sown as early as possible.

White (1967) in one season at Mesopotamia, found best establishment from early August and late September sowings, with a substantial drop in establishment from a late October sowing. Similarly Hart and Jacobson (1979) in Marlborough, showed overdrilling in late September instead of mid-October, more than doubled production in the first spring. Also, Smith and Stiefel (1978) on the Manawatu sand country, showed that May and September sowing were superior to April and October sowings. Hart and Jacobson (1979) and Smith and Stiefel (1978) all concluded that adequate soil moisture at sowing appeared to be more critical for good establishment than soil temperature. Smith and Stiefel (1978) suggested that overdrilling tended to be better than minimum cultivation at later sowings, because of improved soil moisture status, since soil moisture under cultivation was only 12.5% compared to 20.5% for overdrilling.

Hart and Jacobson (1979) noted no adverse effect of frost from their September sowings, and frost was not mentioned as a factor even from the early August sowing at Mesopotamia (White, 1967). This suggests that risk of frost damage can be largely ignored as a critical factor in spring establishment and that sowing should be as early as is practically possible to ensure high soil moisture status.

With oversown lucerne in the semi-arid zone, initial sowing over two seasons by Douglas (1974) showed good establishment in both April and July-August. Subsequent sowings over four seasons, on similar sites, suggested that more reliable results were obtained from August sowings, although good establishment resulted from some March-April sowings (Musgrave *et al.,* 1975). Monitoring soil-moisture status, showed that similar amounts of rain were more effective in promoting establishment in spring, because it was falling on soil at close to field-capacity, in contrast to autumn when soils were normally drier (Musgrave and Lowther, 1976). Thus autumn sowings could probably be done with safety on already wetted soils.

With sowings in early spring Musgrave and Lowther (1976) showed that there were large variations in best sowing date between different sites. Musgrave (1977a) further demonstrated over two seasons, that for both lucerne and white clover sowings on widely differing sites, maximum establishment occurred when the mean 10 cm soil temperature in the period following establishment was in the range 3-7 °C (Fig. 3). This corresponded to a sowing period of early August — early September for a sunny face at 880 m altitude, early September — early October for the corresponding shady face and mid-August — mid-September for a sunny face at 1070 m. On either side of these sowing times establishment was substantially reduced. It was suggested that the poor establishment at low temperatures was due to slow germination of seed, since germination rate of lucerne is very temperature-dependent over the range 0-5 °C (Young *et al.,* 1969). The poor establishment from later sowings appeared to be related more to rapidly declining soil moisture, which were highly correlated to soil temperature over this period (Musgrave, unpubl. data).

Young *et al.,* (1969) have shown that germination percentage of lucerne seed at 0.1 °C was 6% of the maximum but this increased rapidly to 82% at 5 °C and 98% at 10 °C. Other studies confirm that germination rate of lucerne is relatively insensitive to temperature over the range of 5-30 °C (Townsend and McGinnies, 1972; McWilliam *et al.,* 1970). Thus it seems likely that it is only when winter temperatures fall substantially below 5 °C, that low temperatures become a major factor limiting establishment. Such low temperatures usually occur regularly only in the high country and on shady aspects in the hill country (Musgrave, 1980) and it is only in these areas that the relationship between temperature and establishment described by Musgrave (1977a) is likely to apply.

With oversown lucerne in the sub-humid zone, the only study of the effects of time of sowing has been in the North Island pumice country. Baars *et al.,* (1981) showed over two seasons that sowing in the period mid-July to late September gave good establishment, but that earlier or later sowings were less successful. This was a similar pattern to that found for clover establishment from oversowing in a similar area (Toxopeus, 1972). Baars *et al.,* (1981) suggested that this establishment was related to the period when the soil was at, or near, field capacity, since soil temperatures were adequate (McWilliam *et al.,* 1971; Musgrave, 1977a) and long-term rainfall records show that their rainfall is highest and least variable in August.

The point to be made in both oversowing and overdrilling situations is that sowing should be made as early in the late-winter — early-spring period as possible when surface moisture levels are likely to be at a maximum. This will allow maximum growth of seedlings before the onset of drought.

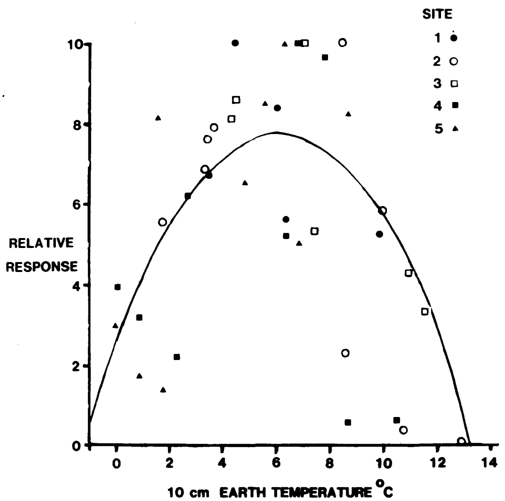

Figure 3: Seedling establishment of clovers relative to the best establishment at each site (=10) in relation to soil temperature (after Musgrave, 1977b).

PESTS AT ESTABLISHMENT

The normal pest problems associated with establishing lucerne have been covered by Wynn-Williams (Paper 2). However, there are special pest problems associated with oversowing. Detailed studies of losses during the establishment period in Australia, showed that seed harvesting ants removed as much as 40% of the seed sown (Campbell and Swain, 1973a). Fortunately ants do not appear to be a problem in New Zealand, but as early as 1948, Suckling (1949) observed large losses from birds and slugs in large-scale sowings. Baars *et al.,* (1981) attempted to define the extent of the bird problem, and found that establishment on unnetted plots was only 10-30% of that from netted plots, but that unspecified amounts of longer cover reduced losses by about 10%. Losses of this magnitude suggest that seed coatings for oversowing should be dyed green, which is standard practice to minimise bird theft when sowing lawns or to protect birds from a poison bait.

Slug damage can cause total seedling loss (Suckling, 1951) although in drier environment losses from slugs are small (Campbell and Swain, 1973a). In a controlled environment Charlton (1978a) showed that a seedling mortality of 85% due to slugs, was only reduced 20% by methiocarb coatings, but similar coatings proved ineffective in field sowings (Charlton 1978b). Rhodes (1981) found little effect from the use of diazinon or DDT/lindane in two seasons. However, neither DDT nor lindane are effective against slugs (van der Gulik and Springett 1980) so that slugs may still have been responsible for some losses. Slugs can also be a major problem in overdrilled situations (Baker, 1979; Pottinger, 1979) but preliminary results suggest that methiocarb prills can be effective in reducing losses (J.F.L. Charlton, pers. comm.).

Grass grub attack has caused major seedling losses on occasions in both oversown (White and Meijer, 1979) and overdrilled (M.J. Daly pers. comm.) situations, and pests in general are likely to be a more serious problem than in cultivated situations (Pottinger, 1979).

EARLY MANAGEMENT

Cockayne (1922b) showed that heavy stocking with a large mob following oversowing, was very successful in increasing lucerne germination by improved soil/seed contact, an effect also noted by Suckling (1949) and McNeur (1966) with clovers. Baars *et al.,* (1981) trampled oversown lucerne with 400 hoggets/ha and improved plant establishment by 50%. This response was attributed to breaking up the very dense turf mat which was present.

Frequent light grazings have been used to minimise competition between the existing sward and oversown clovers and grasses (Suckling, 1951; Cullen, 1971). This treatment should not be used with lucerne as it is sensitive to frequent defoliation, although Musgrave (1972) has suggested that a single early weed-control grazing may be beneficial. Thus the importance of ensuring complete suppression of the existing vegetation with the appropriate herbicides is re-emphasized. Atkinson (1976) has shown a large lucerne yield response to a post-emergence herbicide treatment of propyzamide and 2,4-D, in spite of low weeds levels.

CONCLUSION

The agronomic advantages of lucerne in dry hill country can be great and have been demonstrated in the semi-arid zone of North Otago (Musgrave *et al.,* 1975; Musgrave 1976, 1981), the sub-humid zones of North Canterbury (White and Meijer 1979), Nelson/Marlborough (Clare *et al.,* 1981), the Manawatu sand country (Smith and Stiefel 1978) and the pumice country (Baars *et al.,* 1975).

Widespread adoption of oversowing and overdrilling has been hampered by general problems with lucerne over recent years. There are however special problems associated with the non-arable situation. In sub-humid areas the major problem appears to be obtaining reliable suppression of the existing vegetation over the establishment period. Provided other factors such as lime requirements, inoculation and coating are attended to, adequate populations of lucerne are attained with reasonable reliability, when vegetation suppression is achieved. Although there has been a considerable amount of experimental work done to assess the usefulness of various herbicide combinations, the factors that effect their ability to work in the range of conditions in which lucerne may be sown are not yet fully understood. I believe that our rate of learning in this field could be greatly increased by devoting more attention to the treatments which "failed", in the publishing of experimental results. These treatments were presumably included in the experiment, in the expectation that they could to the job required, yet far too often no information is given as to how they failed to give the desired level of control. Failures can contribute as much to our learning as successes. In the pumice country, where considerable areas of lucerne are being overdrilled, intelligent observation of the results being achieved has allowed advisors to build up a very useful depth of experience on which to base their advice (B.G. Koller pers. comm.).

In the semi-arid areas, the factor most limiting reliable establishment is lack of effective rainfall. Thus, factors such as time of sowing, inoculation and pelleting techniques and the place of lime, need critical attention to increase the chances of establishment. With the existing technology, Musgrave (1977b) suggested that worthwhile establishment could be obtained in all areas, with annual rainfall in excess of 500mm. In areas receiving less than 500mm rainfall, the results suggested that useful establishment can generally only be expected at higher altitudes (6-700 m) on sunny faces, or on low altitude shady faces.

The major question which needs to be answered for these marginal conditions is — can the considerable expense involved in oversowing lucerne be justified? Cockayne (1922a) noted the very early-spring growth of lucerne in this environment. More extensive evaluations of alternative legumes have confirmed that this early-spring growth is a major attribute of lucerne on dry, low altitude, sunny faces (Musgrave, 1977b and 1981a). In an attempt to evaluate the worth of such production to a property, data on costs of establishment and subdivision to allow for adequate management, and productivity have been used in a linear programming model of a run system, with a wide range of options (Musgrave 1981b). This showed that oversown lucerne could very profitably be included in the development programme, to provide the very early high-quality feed required for ewes prior to lambing.

There are of course many deficiencies in our knowledge of the requirements for successful lucerne establishment from oversowing and overdrilling. I would suggest that the more important of these would be in the fields of coulter design for overdrilling machinery, the selection of strains of rhizobia with better survival characteristics, and improved seed-coating techniques, to improve the nodulation phase of the establishment process.

SUMMARY

Research has shown that overdrilling is superior to oversowing. The use of a chisel-opener and bar-harrow have been shown to give better establishment when overdrilling in dry conditions. Lime should be used on soil with a pH of $<$ 5.8, but a small response is consistently obtained on less acid soils. Lime should be placed in the drill row when overdrilling lucerne. The presence of cover promotes establishment from oversowing, but lucerne is very sensitive to competition at establishment and the use of herbicides is essential for successful establishment in most environments. Differences in establishment and productivity between cultivars have been small, but grazing-type cultivars are likely to persist better. For oversowing, seeding rates of 5 and 10 kg/ha are suggested for the semi-arid and sub-humid zone respectively. The use of inoculation at up to ten times normal rates and lime-coating are essential when oversowing. The use of an elemental sulphur coat may also have a place in the semi-arid zone. Sowing should be as early in spring as possible, when soil moistures are high, except in cold environments where soil temperatures in the range 3-7 °C are desirable at sowing.

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