Tropical pasture establishment. 7. Sowing methods for pasture establishment in northern Australia

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Abstract

A wide range of sowing methods and machinery are used for sowing pastures in northern Australia. In many cases, the sowing method is a compromise between agronomic desirability, practicality and the desire to minimise establishment costs. The most important 2 processes in pasture establishment are the amount of seed which germinates and emerges, and the number of those seedlings which develop into mature plants. In an environment characterised by high levels of evapotranspiration over summer, the amount and distribution of rainfall following sowing have a major influence on pasture establishment. Survival and growth of seedlings are also influenced markedly by competition from established plants. This paper discusses the choice of sowing method and how it can influence the processes of germination-emergence and seedling survival. Sowing methods that provide good soil-seed contact and place seed at an optimum depth in the soil can maximise germination and emergence and provide for the efficient use of seed. The need for reliable sowing methods is emphasised. Sowing methods which control plant competition and facilitate soil moisture storage partially reduce problems of unreliable pasture establishment associated with variable rainfall.

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Introduction

In subtropical and tropical areas of northern Australia, the quality and quantity of pasture available for grazing animals can be increased by sowing species that are more nutritious and productive. This can involve the complete replacement, or the augmenting, of existing pasture with legumes and/or grasses. It may also involve re-establishment of pastures in old cropping areas. Fertiliser, containing phosphorus and sulphur and sometimes one or more trace elements, is usually required to maximise growth of the sown species on low fertility soils.

High radiation and high temperatures during summer in northern Australia, together with variable and erratic rainfall, make pasture establishment a risky procedure in many areas. A high proportion of the rain falls as high intensity thunderstorms during summer, and is commonly associated with hot, sunny conditions that lead to rapid drying of the soil surface following rain (Miller and Perry 1968; Winkworth 1969; McKeon and Brook 1983; Cook 1984). Most favourable conditions for establishment occur when low pressure cyclonic and other rain depressions bring 3 or more consecutive days of rain and overcast conditions.

Many of the soils on which pastures are sown are of low fertility, have poor structure, often with a hard-setting surface, are located on sloping ground, and are highly susceptible to erosion if cultivated.

A wide variety of methods are used for sowing pastures in northern Australia. They include everything from allowing cattle to spread the seed through dung when they graze, and broadcasting seed into existing pasture by aeroplane, fertiliser spreaders and drum seeders, with or without prior soil disturbance, through to the use of specialised and precision seed drills on fully cultivated seedbeds. This diversity of sowing

methods involves the use of a wide range of machinery, often obtained second-hand from grain-growing regions. Many landholders involved in cattle grazing enterprises have only limited experience with planting machinery and have little interest in acquiring and using it. Many are of the opinion that the 'best tractor is a contractor' and, where they have to use machinery, prefer sowing methods which minimise its use. This has led to the widespread use of rough, one-pass sowing methods with seed boxes mounted on chisel and disc ploughs.

This paper outlines the main sowing methods currently in use in northern Australia, assesses their performance and considers their strengths and weaknesses. As performance is likely to vary widely from one region to the next, and from year to year, depending on the amount and distribution of rainfall following sowing, we assessed sowing methods in terms of the biological requirements for pasture establishment. An economic assessment of different pasture improvement strategies is covered by MacLeod *et al.* (1993).

Requirements for pasture establishment

For pastures to establish, a seed must germinate, then develop roots and leaves and finally grow into a mature plant. Pasture establishment can be subdivided into 2 distinct phases: seed germination and emergence, followed by seedling growth and survival. The length of the germination-emergence phase varies according to the rate of germination of the species being sown: 2–3 days for Caribbean stylo (*Stylosanthes hamata*) (Mott *et al.* 1976); 3–5 days for Siratro (*Macroptilium atropurpureum*) and round-leafed cassia (*Cassia rotundifolia*); and 8–10 days for podded seed of shrubby stylo (*S. scabra*) (Mott *et al.* 1976). In this paper, pasture establishment is considered over a period of 12 months. For perennial species, this involves persistence of seedlings over the first winter, or dry season, until they start to grow the following summer. For annual species, it involves seed set at the end of the first growing season, followed by successful seedling regeneration in the second season.

Germination and emergence

To germinate, a seed must imbibe water from its surrounding micro-environment. The rate of imbibition depends on the soil water content and the degree of contact between the seed and the moist soil. If seed is broadcast on to the surface of an undisturbed soil, it can imbibe water only through the small area of seed coat that is in contact with moist soil (Sedgley 1963). The exposed seed surface also loses water to the surrounding micro-environment. In this situation, the prevailing weather conditions (Winkworth 1969) and micro-environment surrounding the seed can have a major impact on germination (Miller and Perry 1968; McWilliam and Dowling 1970). The presence of surface cover can slow moisture loss and reduce the rate of drying of the soil surface (Rickert 1973; Mott *et al.* 1976; McIvor and Gardener 1985), especially where hot sunny conditions occur during the germination phase. Conversely, treatments which destroy cover (e.g. burning) can reduce germination.

Soil disturbance increases soil-seed contact and leads to higher rates of imbibition, and hence germination. Compressing soil around the seed by rolling or use of press wheels further improves emergence (Choudhary and Baker 1980; Ward *et al.* 1991), the advantages being most evident in sandy or loamy soils, particularly where moisture for germination is limited.

Drilling seed into the soil at the optimum depth for the species being sown provides the best conditions for germination and seedling emergence. Seed placement and depth of sowing are important considerations where small-seeded pasture species are being sown following one or more cultivations of the soil. More seed is probably wasted by planting too deep than too shallow. Although most small-seeded pasture species have optimum planting depths of 10–20 mm (Cook *et al.* 1987), most commercial seed drills do not have adequate depth control to consistently place seeds at these shallow depths, especially if the soil surface is uneven. Consequently, seed is often broadcast or dropped on to the surface of cultivated soil and either lightly harrowed or rolled. The success of this practice will depend on the roughness of the soil where the seed is dropped. Small seeds can fall down depressions and crevices if the surface is rough and cloddy. Seeds can be buried 20–30 mm

deep, a depth from which they are often incapable of emerging if rain causes the soil to move or if the seedbed is harrowed or rolled.

Seedling growth and survival

Seedling growth and survival depend on the availability of resources such as soil water, nutrients and light. The demand for resources varies between species. For example, legumes belonging to the genus *Stylosanthes* are able to grow at lower soil phosphorus levels than Siratro (Coates *et al.* 1990; Jones 1990), glycine (*Neonotonia wightii*) or white clover (*Trifolium repens*). Soil nutrient deficiencies can be overcome with fertiliser, but soil water content relies largely on the amount and distribution of rainfall received. Plant competition can modify the availability of resources to the seedling and have an overriding impact on its growth and survival (Cook *et al.* 1993). Dry periods, which are common throughout the summer months in most areas, can result in significant seedling deaths and establishment failure, particularly where plant competition is present (Cook and Dolby 1981; Cook 1984; Lowe and Bowdler 1991). In some areas it may be possible to select a time of year for sowing when there is a greater probability of receiving frequent rainfall events, or avoiding high radiation and evapotranspiration, to minimise the chances of encountering adverse establishment conditions.

Sowing methods

Sowing methods used for establishing pastures in northern Australia provide a range of conditions for establishment, largely through differences in soil disturbance. Sowing methods can be grouped into those which aim to replace the existing pasture and those which aim to augment the existing pasture.

Replacement of the existing pasture

There are 2 main methods of sowing which aim to replace the existing pasture with sown species. They are fully cultivated seedbeds and direct drilling. In both cases seed is drilled into the soil to optimise soil-seed contact while plant competition is eliminated by cultivation, in the case of fully cultivated seedbeds, or by herbicide, in the case of direct drilling. Since these methods provide the best control of plant competition, they give the most reliable pasture establishment and are the best methods to use when sowing grasses. Both methods require cleared country to allow machinery to work. However, pasture establishment costs are relatively high (MacLeod *et al.* 1993), and are even more expensive if the land has not already been cleared.

Cultivated seedbeds. Fully cultivated seedbeds involve at least 2, and often 3 or more cultivations with offset disc or chisel ploughs and scarifiers, the first cultivation taking place some time (e.g. 2–4 months) before the proposed planting date. Seed is usually sown at the final cultivation, through either a combine drill, or a roller-drum seeder attached to cultivation equipment. Alternatively, a fertiliser spreader may be used to distribute seed in a separate operation. Fully cultivated seedbeds possibly provide most reliable establishment, particularly where a fallow period ensures good weed control and allows for soil moisture storage prior to sowing. Where these principles have been followed, cultivated seedbeds have resulted in successful pasture establishment in some very dry summers (Cook *et al.* 1993). However, because of the high costs involved, use of cultivated seedbeds tends to be restricted to the more productive soils where pastures are used more intensively. They are the best method for establishing tree legumes such as leucaena (*Leucaena leucocephala*) (Clem *et al.* 1993), which is particularly susceptible to competition because of slow seedling growth rates (Cook *et al.* 1993). Cultivated seedbeds are also widely used for establishing ley pastures in cropping areas, or for re-establishing permanent pastures after cropping. In such cases, landholders are usually familiar with machinery and farming practices required for seedbed preparation. However, in situations where old cropping soils are poorly structured and hard-setting, pasture establishment problems are often encountered (Roe 1974). Furthermore, cultivated seedbeds are generally inappropriate in hilly country, where soil erosion is likely to be a problem.

Depth of sowing can be a problem with cultivated seedbeds. Even the furrow depressions

created by a combine drill in a soil of fine tilth can result in seed being buried too deep if it is harrowed or rolled after the seed is dropped (Toms 1958). A more satisfactory planting depth is likely to be achieved if the soil is worked to a fine tilth, and then harrowed to fill depressions and crevices before the seed is dropped. A final harrowing, or preferably rolling to improve soil-seed contact, will then work or press the seed into the surface 5–10 mm of soil and achieve a better result. Cheap, mechanical aids that enable combines to place small seeds at a consistent shallow depth have also been developed (Butt 1988). Such options are likely to be highly cost-effective as failure of seed to emerge is a common result of seed being sown too deep.

Direct drilling. Direct drilling involves sowing seed into a chemically killed sward, usually with heavy duty drills specifically developed for this purpose (Breakwell and Jenkins 1953; Decker *et al.* 1964; Baker 1976; Allen 1979). As with the cultivated seedbed, direct drilling is used where the intention is to replace rather than augment the existing pasture. The difference is that existing vegetation is killed with a herbicide rather than removed by cultivation. The time between spraying and sowing can be varied to allow the herbicide to take effect and, where necessary, allow moisture to accumulate in the soil profile. Direct drilling retains cover on the soil and so provides better protection from erosion than fully cultivated seedbeds. This retention of cover may also make it a better option than fully cultivated seedbeds for establishing pastures on areas with poorly structured and hard-setting soils. Direct drilling is particularly useful in wetter coastal areas where cultivated seedbeds can create trafficability problems following rain. Apart from its use on some dairy farms, direct drilling is rarely used for establishing pastures in northern Australia. On the other hand, improvements in technology and falling herbicide prices have increased its popularity significantly over the last 10–15 years in southern Australia. Direct drilling is claimed to be as reliable as a fully cultivated seedbed, although there can be increased problems associated with pests (snails, slugs and insects) and diseases (Charlton 1978; Byers *et al.* 1985).

Augmenting the existing pasture

Some sowing methods, commonly referred to as oversowing, aim to augment the existing pasture with species which are of higher quality and/or higher production. In northern Australia, they are commonly used to sow legumes into native pastures, or run-down sown grass pastures. These methods are usually cheaper than fully cultivated seedbeds and direct drilling methods, but can be less reliable due to incomplete control of plant competition and poor seed placement.

Sod-seeding and rough seedbeds. Sod-seeding and rough seedbeds are one-pass sowing methods that partially disturb the existing pasture in order to facilitate establishment of the sown species. While they can involve specialised heavy duty seed drills or sod-seeders (Breakwell and Jenkins 1953), they commonly involve the use of chisel ploughs or offset disc ploughs in combination with a roller-drum seeder or fertiliser spreader to distribute the seed. Although seed is not drilled into the soil when these machines are used, the soil disturbance created generally results in higher levels of germination than where seed is broadcast in the absence of disturbance. However, usually less than 60–70% of the existing pasture is destroyed, leaving too much competition for reliable pasture establishment (Lowe and Bowdler 1991).

Specialised implements such as the 'crocodile' seeder have been developed to drop seed into small holes or pits, dug by the implement. The 'crocodile' is a robust implement particularly well suited to reseeding degraded areas of pasture with low grass cover and where run-off following rain can be high. The pits collect water and can create a favourable environment for seed germination. However, the size of the gap formed (Cook *et al.* 1993) in the creation of the pits (about 30 x 20 cm) is unlikely to provide adequate control of plant competition in areas where there is strong grass growth.

Competition can be significant in rough seedbeds which create only partial disturbance. This can lead to establishment failure when small falls of rain (20–30 mm) are followed by dry periods in the first 4–6 weeks of a seedling's life. With one-pass sowing methods, limited storage of soil water prior to sowing makes them less

reliable than fully cultivated seedbeds or direct drilling for pasture establishment.

Strip planting methods. Pasture is sown in strips, usually covering from one-quarter to one-half of the existing pasture, mainly as a cost saving measure. Strip planting is also used for erosion control in sloping areas and as a means of sowing pasture in partially timbered areas. It usually involves cultivating one or two machine widths, then leaving an area, 1–3 times the width of the strip, before commencing the next strip. Strip planting was originally developed as a one-pass sowing method for use with the annual Townsville stylo (*Stylosanthes humilis*) (Graham 1963), a species that establishes rapidly and sets large amounts of seed. However, some land holders now cultivate strips 2 or 3 times (as with fully cultivated seedbeds) to achieve greater reliability when sowing slowly establishing and less drought-tolerant perennial species. Seeding rates are commonly increased 2–3-fold when one-half or one-third of the area is being covered, respectively, in an attempt to improve and speed up establishment. On low fertility soils, addition of fertiliser to sown strips can increase both the growth and seed set of legumes, an important consideration in oversown pastures. However, fertiliser application can add substantially to overall establishment costs if it requires an additional pass with machinery (MacLeod *et al.* 1993). Animals may also concentrate on, and overgraze the strips, thereby reducing seed set and slowing legume build-up in the pasture. The sown species also have a greater distance to spread to colonise the whole pasture.

Band-seeding. Band-seeding is a specialised form of sod-seeding that was specifically developed to provide positive control of plant competition and a more precise seed placement than other oversowing techniques (Cook *et al.* 1992). The machine can drill seed at a consistent shallow depth of 5–10 mm even under rough operating conditions. A 50 cm wide band of systemic herbicide (glyphosate) is sprayed over the row to control plant competition and a wide row spacing (1.5 m) is used to minimise inputs of herbicide, seed and fertiliser. This wide row spacing, together with a high under-frame clearance, also allows the machine to operate in partially cleared country containing stumps, logs and rocks. Since two-thirds of the existing pasture remains, and most tropical legumes are not actively sought by grazing livestock until late in the growing season, grazing can continue during and after the planting operation, with little effect on tropical legumes.

Although not as reliable as a fully cultivated seedbed, band-seeding provides effective and reliable establishment, especially during dry conditions (S.J. Cook, unpublished data). However, seedlings survived the dry conditions only where the herbicide killed at least 90% of the existing pasture in the bands and where there was adequate soil moisture in the bands below the seedlings. To obtain adequate moisture in the bands, it has to be either 'trapped' at sowing, or sufficient rain needs to be received after sowing. For the herbicide bands to 'trap' sufficient moisture at sowing, the soil profile has to be fully wet. It then takes only relatively small falls of rain (15–25 mm) to rewet the profile in the bands. Conversely, a number of establishment failures have occurred where legumes have been band-sown into seedbeds with little or no soil moisture. As with other oversowing methods, this is usually the result of conditions turning dry after receiving sufficient rain to germinate the seed, but insufficient to wet up the soil profile in the bands. Relatively poor establishment has also been recorded in situations where less than 60% of the pasture has been killed by the herbicide, even where rainfall has been adequate.

Once fully wet, the herbicide bands can sustain adequate seedlings during 3 months of hot, dry conditions (S.J. Cook, unpublished data). Round-leafed cassia, shrubby and fine-stem stylos, and Siratro have been successfully established under very dry seasonal conditions, in what were the 4th and 5th driest summers in 104 years of rainfall records (Cook *et al.* 1992). During this time, adequate soil moisture was retained under the bands while the profile dried out completely in the inter-row areas less than 1 m away (Figure 1).

Surface broadcasting or aerial seeding. Surface broadcasting of seed, whether carried out by aerial or ground methods, simply involves dropping the seed on to the soil surface within

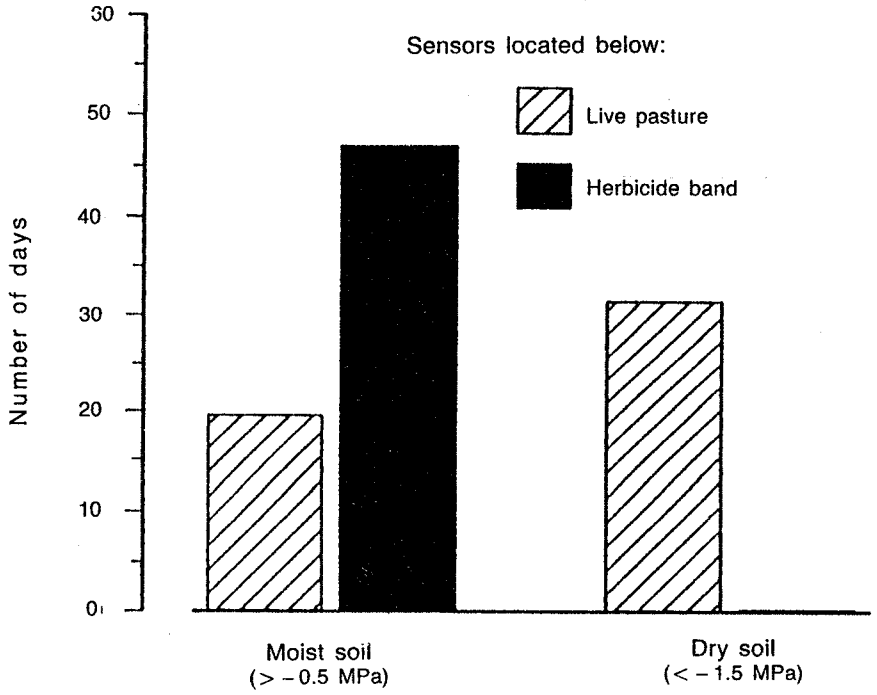

Figure 1. Number of days when the soil at a depth of 30 cm under a black speargrass pasture was either moist (> −0.5 MPa) or dry (< −1.5 MPa) during a 65-day period, starting 16 January 1990. Sensors were either located below the centre of 50 cm wide herbicide bands, or below live native pasture about 75 cm away.

an undisturbed pasture, often following a fire. With aerial seeding, large areas can be covered quickly and it is relatively cheap if fertiliser is not applied (MacLeod *et al.* 1993). It is often the only option for sowing legumes over large areas, for hilly country that is too steep for machines, or for areas that have not been cleared of dead trees, stumps, logs and rocks. Surface broadcasting is generally not suitable for grass establishment because of competition from existing native grasses (Cook and Dolby 1981; McIvor and Gardener 1981; Thomson *et al.* 1983). Even with legumes, surface broadcasting gives unreliable establishment in many parts of Queensland, largely because of root competition from existing native grasses, aggravated by periods of moisture stress (Cook *et al.* 1987). Neither burning nor heavy grazing provides sufficient relief from root competition to sufficiently improve seedling survival (Cook 1984). On the other hand, where tree thinning or removal and pasture development are part of a property development program, surface broadcasting has a much higher chance of success if legumes are oversown at the time of tree clearing (Cook 1984; Cook and Ratcliff 1992).

Distribution of seed by cattle. Animals ingest large numbers of seeds during grazing. Some seeds pass through the animal undigested and are deposited in the dung. The amount and viability of seed available for establishment depend on animal species, seed size, roughage intake, digestibility of the associated diet, the amount of seed consumed, hardseededness and whether the seed is contained in a pod or burr (Curll and Jones 1989). The percentage of seed passing through the digestive system can range from 2% (Carter 1980) to over 50%, with cattle digesting less seed than either sheep or goats (Simao Neto *et al.* 1987). Less seed passes through the digestive tract if the animals are grazing a low quality diet (e.g. 45% digestibility) compared with a higher quality diet (e.g. 60–70% digestibility) (Jones and Simao Neto 1987). Legume seeds generally survive passage through the digestive tract better than grasses, with seed survival being largely dependent on the degree of hardseededness

(Simao Neto and Jones 1986; Gardener *et al.* 1993). Less hard seed is digested than soft seed, and hard seed is also more resistant to damage in moist dung (Simao Neto and Jones 1986).

Establishment of seed in dung depends on seasonal conditions and competition from surrounding plants. Dry dung pats raised above the soil surface are difficult to wet up and dry out quickly, making them difficult sites for seedling establishment. Furthermore, dung is not distributed evenly over the paddock but tends to be concentrated in cattle camps (e.g. Hilder 1964) and around watering points. While it is possible to feed pasture seed to animals as a distribution method, losses of seed occur during digestion, survival of seedlings in dung pats can be poor and seed is distributed unevenly. Commercial seed is also likely to have a lower hard seed content, further increasing seed losses. These combine to make it an unattractive option, especially when seed is expensive. A better option would be to sow a legume 'seed crop' in a corner of the paddock and allow the animals access to it when the seed is ripe. However, the time taken to gain any benefit from a pasture sown in this way is likely to be prolonged, probably exceeding 10 years.

Other sowing methods

Blade ploughing. Roller-drum seeders are often mounted on blade ploughs used for the control of woody weeds. The blade ploughing operation itself is very expensive and so tends to be confined to more productive-responsive soils, e.g. control of brigalow (*Acacia harpophylla*) regrowth. Establishment of the pasture is secondary to the control of the woody weeds. Otherwise, the high cost and low–moderate reliability of the rough seedbed would not justify its use as a pasture sowing method. Seed is simply broadcast on to the surface after the passage of the blade plough, in a one-pass operation. The success of establishment is largely related to the amount of competition which remains and the amount and distribution of rainfall following planting. The amount of competition will depend on the success of killing the woody weeds and on the amount of grass and other herbaceous species present prior to the operation. Blade ploughing is likely to have little effect on these herbaceous species unless it is followed by a long dry spell. Under such dry conditions, most of the established plants are killed, improving the chances of successful establishment. A range of pasture species can be sown in this way, but most success has been achieved with those which are less sensitive to planting depth and have high seedling vigour e.g. Silk sorghum (*Sorghum* spp.) and purple pigeon grass (*Setaria incrassata*).

Cover cropping. Cover cropping is sometimes used for establishing pastures and is a method commonly used for establishing medics (*Medicago* spp.) in rotations with cereal crops. A fully cultivated seedbed is normally used. With cover cropping, the costs of pasture establishment are offset against returns from the cereal cash crop. On the other hand, this practice is difficult to justify from the viewpoint of pasture establishment *per se* because competition from the cover crop significantly suppresses pasture growth in the first year (Donald 1963).

Concluding remarks

The most important processes in the establishment of a pasture are the amount of seed which germinates and emerges, and the number of these seedlings which survive and develop into mature plants. The amount and distribution of rainfall following sowing have a major influence on the outcome of these processes (Miller and Perry 1968; Winkworth 1969; McKeon and Brook 1983; Lowe and Bowdler 1991) as the soil surface layers dry rapidly when high radiation and high temperatures prevail throughout tropical areas. Choice of sowing method can also have a major influence on the processes of germination and seedling survival. Sowing methods which control plant competition and facilitate soil moisture storage are able to partially offset unreliable rainfall. However, even on fully cultivated seedbeds, rapid drying of the surface of self-mulching clay soils has been a major problem in reducing emergence of small-seeded grasses such as green panic (*Panicum maximum* var. *trichoglume*) and rhodes grass (*Chloris gayana*) (Leslie 1965). Again, selection of appropriate sowing methods or management practices which retain or utilise surface cover or mulch can help overcome this problem (Rickert 1973).

In the more intensive coastal and subcoastal areas of northern Australia, cultivated seedbeds have been found to be a reliable method of pasture establishment (Jones and Rees 1973).

High levels of pasture production were achieved within the first 12 months, particularly where >100 kg/ha of superphosphate was applied at sowing. However, it is often not practical or economic to provide such conditions, particularly where extensive areas of low fertility soils are to be sown. The method of establishment chosen therefore tends to be related to the intensity of agriculture in the region, the class of land being developed, climatic factors, species being sown and whether or not the sown pastures are intended to completely replace or augment the existing pasture. In many cases, the sowing method used is a compromise between what is agronomically desirable, what is practical under the circumstances, and the desire to minimise input costs. However, whatever sowing method is used, it must be capable of enabling sufficient numbers of plants to establish and provide an agronomically and economically acceptable development option on an average of at least 6–7 years in 10.

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