

# **SEED- AND SOIL PREPARATION TECHNIQUES' INFLUENCE ON THE ESTABLISHMENT AND GROWTH OF THREE COMMON SUBTROPICAL PASTURE SPECIES**

by

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## DECLARATION

I, Dirk Jacobus Coetzee declare that the thesis/ dissertation, which I hereby submit for the degree MSc (Agric) Pasture Science at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

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**D. J. Coetzee**

December 2014

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## ABSTRACT

# Seed- and soil preparation techniques' influence on the establishment and growth of three common subtropical pasture species

by

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It is often a challenge to successfully establish perennial pastures which in turn determines the production potential and persistence thereof. Three perennial subtropical grass species commonly cultivated in South Africa are *Eragrostis curvula* (var. Ermelo), *Digitaria eriantha* (var. Irene) and *Chloris gayana* (var. Katambora).

The secret of successful planted pastures lies in the execution of good seed- and soil preparation techniques; also referred to as pre-establishment techniques. These techniques include: seed conditioning by coating seed with either conventional coating or a coating that contains Mycortex, that differs in only adding mycorrhizza; adjusting the seeding rates recommended by industry which potentially causes intra-species competition (competition between plants of the same species); planting an annual nurse crop with a perennial species which potentially causes inter-species competition (competition between plants of different species); and controlling seedbed qualities before planting and consolidating the seedbed after planting.

There were four experiments conducted (Randomized Block Design) in a controlled environment of a Phytotron. In these experiments the growth factors like water, temperature and soil variance were controlled. It must be kept in mind that conclusions made from data obtained in these experiments cannot be extrapolated to field conditions. *Digitaria eriantha* and *C. gayana* were only assessed in two small experiments as uncoated and coated (conventionally- and Mycortex coated) seed. *Eragrostis curvula* was measured in two experiments as uncoated and conventionally coated seed and was also evaluated at different seeding rates, planted with and without an annual nurse crop (*Eragrostis tef*) and where seedbed consolidation was done after planting. The treatments were replicated between three and six times in the four experiments.

It was found that coated seed does not significantly improve establishment of any of the test species. Adapting the *E. curvula* seeding rate had no significant effect because of the favourable environment created. Consolidating the seedbed caused a lower emergence and yield of *E. curvula* as a result of an anaerobic condition being generated around the seed. The nurse crop planted with *E. curvula* caused an increased yield in the first season. Pre-establishment techniques applied as treatments in these controlled experiments were not as effective as hypothesized in a controlled environment.

There were three field experiments conducted (Randomized Block Design) in uncontrolled environments. Establishment success of test species were evaluated as a response to variable seeding rate treatments, of uncoated and conventionally coated seed; additionally, *D. eriantha* and *C. gayana* Mycortex coated seed was also used. The establishment success of the perennial test species was also measured as being influenced by an annual nurse crop (*Eragrostis tef*). The experiment included the evaluation of establishment success of *E. curvula* where seedbed quality was controlled through preparation techniques; rotavating before planting and consolidating the seedbed after planting.

It was concluded that a higher seeding rate gives a better first season plant density. However, in season two, the optimum plant density was reached for *E. curvula* and *C. gayana* and there were no differences between seeding rate treatments. This

was as a result of intra-species competition in season one, resulting in plants out-competing one another. The creeping growth characteristics of *C. gayana* also contributed to this result. One of the main functions of the nurse crop planted with a perennial grass species is to create a more “favourable” competition as opposed to aggressive competition from weeds. The establishment success of perennial species was lower, where nurse crops were included as a result of inter-species competition. From the second season data it can be seen that *D. eriantha* and *C. gayana* did not have lower plant densities where a nurse crop was planted, whereas *E. curvula* still had lower plant densities. All species had a significantly higher pasture density in season one where uncoated seed was used due to a higher number of seed planted at the same seeding rates on a weight basis. Nevertheless, in season two, the *E. curvula* and *C. gayana* plant densities showed no significant differences between the seed conditioning treatments. This is attributed to the small seed size and shape of *E. curvula* and the creeping growth characteristics of *C. gayana*. Controlling the seedbed quality was found to be unsuccessful for *E. curvula*. The field experiment results highlight the interactive effects between seed coatings, seeding rates and nurse crop treatments as a function of selected species.

The insignificant results obtained from the controlled environment study support the original hypothesis that favourable growing conditions reduce the functions of pre-establishment techniques during the facilitated establishment of sown pasture seed. The significant results from the unfavourable field study support the original hypothesis that adjusting the seeding rates and the use of a nurse crop does have significant effects on the establishment success of the perennial species. It also confirms that conditioning of seed by using coating substances does have significant effects on the establishment success of the perennial species. Controlling the seedbed quality does not have significant effects where pastures are irrigated until establishment.

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# CHAPTER 1

## Literature review on seed- and soil preparation techniques' influence on the establishment and growth of three common subtropical pasture species

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### Summary

Modern day farmers are forced to farm more intensively to optimize production on smaller patches of arable land. This can be achieved by farming more scientifically. Planted pastures form an integral part of the intensification of enterprises, such as stock farming, as part of the fodder flow planning. To optimize the production of planted pastures, it is essential that water, oxygen, temperature and soil quality requirements are met to ensure good germination, emergence and establishment. Seed- and soil preparation techniques such as seed treatments (more specifically the coating of seed), adjusting the seeding rate, the use of a nurse crop, proper seedbed preparation through intensive cultivation using a rotavator and light seedbed consolidation can play pivotal roles in the success of establishment. In addition, it is important to select a species that is adapted to the specific climatic conditions of a specific area while keeping in mind the proposed system of utilization.

### Background

The human population of South Africa is increasing exponentially, while the land available for beef or mutton production does not allow these enterprises to grow according to the growing demand (Aucamp 2000). Arable land is becoming scarcer and livestock farmers have to farm more intensively and scientifically in order to keep up with this ever growing demand (Bartholomew 2000, Foley 2011).

Veld forms an integral part of a fodder flow programme for many livestock farmers. However, more than two decades ago, Dannhauser (1991) reiterated the importance of planted pastures as a result of rapid veld deterioration. The cultivation of pasture- and more specifically grass species can replace and/or supplement veld to improve the grazing capacity of an area. This is essential for farmers using pastures as a forage source for livestock (Thompson and Poppi 1990, Dannhauser 1991, Bartholomew 2000). Establishment of pastures (replacing veld) in addition to reinforcing veld improves the grazing capacity by increasing the Dry Matter (DM) production per hectare. It can furthermore have a contributory effect on the nutritive value, digestibility and subsequent palatability of the DM produced (Aucamp 2000). This improvement of DM quantity and quality, results in a steep increase of the amount of nutrients grown per hectare.

Before any planted pastures can be utilized, it first has to be successfully established (Dannhauser 1991). Seed germination and seedling establishment stages are where the plant is the most defenseless against environmental factors (Hadas 2004). Successful pastures with high productivity and good quality are the direct result of proper pasture establishment. Pasture establishment can be divided into the following three stages: (i) germination of seed, (ii) establishment of the seedling and (iii) the thickening up of pasture (Loch et al. 1999). Success of stages one and two is critical, as the plants are not completely autotrophic yet, and it is partly dependent on good seed- and soil preparation techniques (hereafter referred to as pre-establishment techniques).

Special care should be taken during establishment of perennial pastures in livestock production systems. Perennial grasses are more vulnerable since they have smaller seeds and are slow to establish. These species have delicate seedlings as compared to other crops and weeds and therefore perennial pastures require more attention during establishment (Dannhauser 1991, McDonalds and Keys 2002). If establishment is poor, it will take expensive and highly intensive management to improve the pasture sward performance. It is therefore clear why McDonald and Keys (2002) made the statement that “the most expensive pasture is the one that fails to establish properly”.

## Seed and seedling requirements

Some of the basic requirements for good pasture establishment are soil with good chemical- and physical qualities and acceptable moisture content in relation to species requirements. Bartholomew (2000) reported that care should be taken with site selection, soil and topographical position that may have an influence on establishment success. A well prepared seedbed is essential for establishment of any pasture species (Dannhauser and De Beer 1987, Dannhauser 1991, Bartholomew 2000).

Most plants will respond directly to variation in soil physiochemical constraints such as soil- acidity, toxicity, salinity and low soil fertility (Singleton et al. 1985 as cited by Thies et al. 1991). Climatic conditions like rainfall, soil- and air temperature, solar radiation and insect predation or disease can also have an impact on plant performance (Caldwell and Weber 1970 as cited by Thies et al. 1991).

The process of germination starts when specific insoluble substrates, which are stored in the seed, are hydrated and hydrolyzed to their simplest form, ready to be used again (Hadas 2004). These new building blocks are formed for embryo growth and subsequent plant growth and development (Koller and Hadas 1982). The germination process includes many different biochemical processes. The change from one process to the next will be determined by either environmental factors and/or endogenous regulators. These environmental factors and regulators are in turn influenced by certain threshold values and the timing with which they are reached (Hadas 2004).

If the environmental conditions are favourable with respect to temperature, moisture and sowing depth and when seed dormancy is not an influencing factor, seeds can hypothetically germinate within two to three days of planting (Hacker 1999).

The following four factors can have an influence on seed germination and seedling establishment in the soil environment: (i) water, (ii) oxygen, (iii) temperature and (iv) mechanical impedance (Hadas 2004).

### ***i. Water***

Two factors that affect the uptake of moisture by seeds are: (i) soil moisture properties and (ii) seed moisture properties (Koller and Hadas 1982). Seeds must have a low moisture content compared to the surrounding soil to allow passive water uptake along a water potential gradient (Hadas 2004).

Imbibition (the first phase of moisture uptake by seeds) needs to occur beyond a critical quantity of water, known as the critical hydration point (CHP). When the CHP is reached, germination will take place (Bruckler 1983a, b as cited by Guerif et al. 2001). Imbibition is dependent on: (i) structural porosity of a seedbed in the direct vicinity of the seed, (ii) the soil water potential (Bruckler 1983a, b as cited by Hadas 2004) and (iii) soil-seed contact (Hadas 1982 as cited by Hadas 2004).

During the hydration stage the seed's respiratory energy requirement increases, exceeding that of a dry seed (Bewley and Black 1982), hence the requirement for oxygen increases once seeds are hydrated for the first time after being planted.

### ***ii. Oxygen***

Oxygen is important as a final electron receptor during respiration, which is the biochemical process supplying energy to the seed (Roberts and Smith 1977 as cited by Hadas 2004). The oxygen requirement becomes higher as the radicle emerges and the respiration increases (Hadas 2004).

Conflict may occur between water and oxygen supply to the seed because oxygen supply is affected by the thickness of the water film on the seed surface and in addition to the seed coat being fully hydrated (Come and Tissaoui 1973 as cited by Hadas 2004). Oxygen becomes more essential to the seed as the soil temperature increases or the seed is under light and/or water stress (Smoke et al. 1993).

Soil gas exchange is critical and soil must be well aerated, especially where CO<sub>2</sub> sensitive species are planted (Corbineau and Come 1995). By preventing crusting or compaction of the soil the gaseous exchange can be improved (Guerif et al. 2001). There is a critical quantity of oxygen necessary before germination can occur (Guerif et al. 2001). There is also a relationship between rate of germination

and oxygen concentration at an optimum temperature and water potential (Al-Ani et al. 1985, Guerif et al. 2001).

### ***iii. Temperature***

Germination will take place within a range of favourable temperatures which is species specific (Dannhauser 1991, Hadas 2004). Tropical, subtropical and temperate species all have their own optimal planting time, determined primarily by season, with soil temperature playing a big role. When irrigation is not possible, the rainfall distribution, soil temperature and season should be considered to determine an optimum planting date (Dannhauser 1991). Soil temperature around the seed and heat transfer in the soil are affected amongst others, by season, soil moisture, soil structure, soil colour and also aspect and latitude of the immediate landscape (Hadas 2004).

### ***iv. Mechanical impedance***

Soil crusting can impede germination and emergence directly by being a mechanical obstruction to seedlings or indirectly by lowering gas exchange from the soil and water infiltration into the soil (Hadas 2004). Obstructions can be eradicated mechanically using implements (Dannhauser 1991). These crusted conditions can be the result of rainfall and drought where dust fills the pores of the soil. Compaction caused by heavy traffic can have similar effects on germination and emergence (Hadas 1997 as cited by Hadas 2004).

## **Pre-establishment techniques**

Various seed- and soil preparation techniques can be applied to ensure the successful establishment of highly productive and stable pastures (Aucamp 2000). Broadcast seeding of pastures is a common practice to establish pastures. This method is, however, more successful in high rainfall areas (Dannhauser 1991).

For optimum subtropical grass pasture production, soil pH (KCl) > 5 [pH (H<sub>2</sub>O) > 6], soil phosphorous (P) levels must be at least 20mg.kg<sup>-1</sup> and potassium (K) levels at least 130 mg.kg<sup>-1</sup> (Pasture Handbook 2007, FSSA 2013). If the pH needs to be

corrected and magnesium (Mg) levels are below  $60 \text{ mg.kg}^{-1}$ , dolomitic lime ( $\text{MgCO}_3$ ) should be used rather than calcitic lime ( $\text{CaCO}_3$ ) (Booyesen 1981).

There are many techniques used all over the world to improve the success with which pastures are established. These techniques include the treatment of seed, altering the seeding rate, seedbed preparation and planting other species in mixtures to facilitate better establishment.

### ***i. Seed treatments***

There are ways to enhance seed germination, both physiologically and physically. Hydration and biological seed enhancements improve the physiological ability of the seed, while seed coating physically adds ingredients to the seed that can promote the seed or seedling performance. Physically, coating can additionally ensure that seeds have similar sizes and shapes, which improve precision planting and seed-soil contact (Copeland and McDonald 2001, Heritage Seeds 2011). Seed pelleting is another method of seed enhancement used when seeds aren't uniform in shape or possibly too small and not of correct weight to be sown as accurately as desired (Smith and Miller 1987 as cited by Copeland and McDonald 2001). The type of seed enhancement used depends on what the need is and how cost effective the different processes are (Halmer 2000).

Pre-establishment technique such as seed coating is a possible method to overcome the vulnerability of the perennial pasture during establishment as a result of small seed and unknown seedling vigour (Heritage Seeds 2011). Seed coating is a process of applying layers of substances such as pesticides, growth stimulators, dormancy breaking substances, limestone, micronutrients and even macronutrients without drastically changing the shape of the seed (Copeland and McDonald 2001, Heritage Seeds 2011). The coating can also contain microbial spores and microbial nutrients which include humates, amino acids and seaweed (Biotechnica, 2011). The seed coat creates an ideal environment in the direct vicinity of the germinating seed (Heritage Seeds 2011) and the cost of total soil amelioration substances like lime and fertilizers could be lowered and any possible environmental damage due to over application of fertilizer and pesticides could be reduced (Copeland and McDonald 2001).

The coating applied to pasture seeds, usually has a basis of a binding- and protective polymer (Heritage Seeds 2011). One significant substance that forms part of coating is lime (Heritage Seeds 2011). The lime helps to rectify the pH of the growing medium in the immediate environment of the germinating seed, allowing nutrient uptake. Low soil pH is one of the most limiting factors affecting crop production (FSSA 2013). Optimizing pH, will not only promote better nutrient uptake by the seedling root, but also improves moisture uptake by the germinating seed, hence successful establishment (Heritage Seeds 2011, FSSA 2013). This technology does not only improve emergence but also gives an added advantage to the emerged seedlings, having an influence on the germination and establishment stages of pasture, especially in unfavourable environments (Heritage Seeds 2011). Additional constituents can be added to the coatings, for example Mycortex S (endo-mycorrhizal fungi). Endo-mycorrhizas are fungi that can form symbiotic associations with most plants. Arbuscules grow into the host plant's root cells through which nutrient exchange can take place between the plant and fungi (Miyasaka et al. 2003). The Mycortex S coating is made up of endo-mycorrhizas in spore form and bio stimulants that are beneficial to endo-mycorrhiza growth and prevents other fungal infections (Biotechnica 2011). Choosing a seed treatment technology to suit the production system or to improve the soil conditions is now possible.

## ***ii. Seeding rates***

Seeding rates can be altered according to the species planted, different planting methods and also the quality of the seed used. If poor quality seed is used, it is advisable to increase the seeding rate to compensate for the expected lower germination potential (Lemus 2008). It is sensible to buy seed that complies with the Plant Improvement Act (Act 53 of 1976); this Act protects the farmer (SANSOR 2014). Buying seed from a reliable seed dealer, with the necessary quality certificates, will save money in the long term (Dannhauser 1991).

According to Bartholomew (2000) the seeding rate can be adapted for the following reasons: (i) purity, (ii) germination percentage, (iii) seed size, (iv) seed weight, (v) soil fertility and soil moisture, (vi) seedbed quality, (vii) sowing method, (viii) pasture purpose and (ix) perenniality of pasture.

Seeding rates must also be adapted to time of seeding. According to Larson and Watson (2005), the recommended seeding rate can be planted when planting early, seeing that there will be more time for plants to tiller. When planting late, the seeding rate can be increased by 10-25%, if it is expected that winter dormancy will occur soon after emergence.

In a study conducted by West and Kincer (2011) different seeding rates of *Panicum virgatum* were evaluated (Table 1.1). The seeding rates in this particular trial varied from a low 4.48 kg.ha<sup>-1</sup> to a much higher 11.20 kg.ha<sup>-1</sup>. Even with this considerable seeding rate increase, the only significant differences in DM yield were observed in the first season. An increased seeding rate can facilitate higher yields in the establishment year.

**Table 1.1:** The Dry Matter Yield ('000 kg.ha<sup>-1</sup>) at four different seeding rates for *Panicum virgatum* for four seasons after planting. Adapted from (West and Kincer 2011).

Seeding Rate (kg.ha <sup>-1</sup> )	2007	2008	2009	2010	Average
4.48	4.69 <sup>a</sup>	12.49 <sup>a</sup>	25.64 <sup>a</sup>	38.88 <sup>a</sup>	20.03 <sup>a</sup>
6.72	6.56 <sup>b</sup>	13.27 <sup>a</sup>	26.36 <sup>a</sup>	38.95 <sup>a</sup>	20.52 <sup>a</sup>
8.96	6.07 <sup>b</sup>	13.15 <sup>a</sup>	24.54 <sup>a</sup>	38.45 <sup>a</sup>	20.17 <sup>a</sup>
11.2	6.63 <sup>b</sup>	13.05 <sup>a</sup>	24.51 <sup>a</sup>	39.12 <sup>a</sup>	20.03 <sup>a</sup>

# Means with the same letter are not significantly different at P>0.05

### iii. Nurse crops

*Digitaria eriantha* is an example of a perennial species and is a slow grower that takes long to establish, especially if environmental conditions aren't favourable. Whenever a farmer wants to establish a perennial species, but is in immediate need of forage, an annual species like *Eragrostis tef* can be planted as a nurse crop with the perennial species to ensure available forage in the first season (Dannhauser 1991, Bartholomew 2000). A nurse crop can also be used where pastures are

planted on erodible soil, especially against slopes, to guarantee the emergence of plants within a couple of days of planting (Bartholomew 2000).

Most importantly; the nurse crop can compete with weed species and create a more favourable micro- and growing environment to facilitate establishment for the perennial species. The nurse crop may also compete with the perennial species (White 1973 as cited by Bartholomew 2000) and care must be taken with the nurse crop seeding rates. When *E. tef* is used as a nurse crop with a perennial species, the focus must remain on the success with which the perennial species establishes and not the improved first season production of the nurse crop.

#### **iv. Tilling**

Pasture establishment can become very expensive and therefore seedbed preparation is one of the most important factors to consider (Macdonald 2005). Conventional, deep tilling, especially on soils with high clay percentages, may be required before planting to ensure good drainage, aeration and eradicating obstructions in the soil (Dannhauser 1991). Three characteristics that are needed for a good seedbed are: (i) fineness and firmness (that ensure good seed-soil contact), (ii) evenness and smoothness (for precise placement of seeds at the right depth) and (iii) a weed-free area as far as possible (to avoid competition by aggressive weed seedlings) (Dannhauser 1991, Macdonald 2005). To achieve the desired seedbed, a tillage implement, such as a rotavator, can be used with fewer tillage actions to provide the seedbed, as opposed to using other methods like harrowing (Marenya 2009). Power harrowing can result in a fine seedbed and subsequently better seed-soil contact (Atkinson et al. 2009) while rotary harrowing can ensure a more consistent seedbed (Douglast Koppi 1997, Atkinson et al. 2009). Both rotavating and harrowing ensures a fine seedbed, however, rotavating is considered being more efficient.

In a study conducted by Henriksson (1989) the effect of the fineness of a seedbed on *Triticum aestivum* was evaluated (Table 1.2). The seedbed fineness had a definite effect on the number of established plants and DM yield. The seedbed was tilled using a harrower. The harrowing intensity specifies the number of times harrowing was repeated, i.e. Low, Medium and High indicates one, two and three repetitions, respectively. Seedbed depth was constant and roughness was quantified

on a scale from 1 (very smooth) to 5 (very rough). Aggregate % indicates the percentage of aggregates smaller than four millimetres.

These different harrowing intensity treatments are significant for DM yield and there are a definite improved number of established plants. No evaluation was done with zero harrowing (control) to determine the significant difference between high intensity harrowing and the control. A finer seedbed can therefore result in higher yields.ha<sup>-1</sup>.

**Table 1.2:** The number of *T. aestivum* plants (plants.m<sup>-2</sup>) and DM yield (kg.ha<sup>-1</sup>) at different seedbed fineness values. Adapted from (Henriksson 1989).

Harrowing intensity	Depth (mm)	Roughness	Aggregate %	Plants.m <sup>-2</sup>	Yield (kg.ha <sup>-1</sup> )
Low	40	2.8 <sup>a</sup>	41 <sup>a</sup>	417	4450 <sup>a</sup>
Medium	40	2.2 <sup>b</sup>	44 <sup>b</sup>	434	4630 <sup>b</sup>
High	40	1.9 <sup>b</sup>	46 <sup>b</sup>	441	4680 <sup>b</sup>

# Means with the same letter are not significantly different at P>0.05

#### v. **Seedbed consolidation**

In forage crop production it is a common practice to roll or consolidate (lightly compact) the seedbed before and/or after planting to improve seed-soil contact and improve seedbed firmness (Dannhauser 1991, Couture et al. 2004).

In an experiment conducted by Monti et al. (2001) the effect of seedbed consolidation before and after planting was evaluated (Table 1.3). The Emergence Index of *Panicum virgatum* was used as parameter in this experiment. The different seedbed preparations that were used are: S = ploughing, cultivating, sowing; CS = ploughing, cultivating, consolidating, sowing; CSC = ploughing, cultivating, consolidating, sowing, consolidating and No-till = no tillage was done. Two varieties of *Panicum virgatum* were planted in autumn; one with a larger seed than the other. No significant differences were observed between treatment CS and CSC even though CSC had a slightly better emergence than CS for the large seed variety. Both CS treatments, however, have significantly better emergence than S for the small

seeds. Consolidating a seedbed before and after planting can be practically or even statistically significant to improve the number of established plants.

**Table 1.3:** The Emergence Index of *Panicum virgatum* using different seedbed preparations. S = no consolidating, CS = consolidating prior to planting, CSC = consolidating prior to and after planting, No-till = no tillage of the seedbed. Adapted from (Monti et al. 2001).

Treatment	Autumn	Autumn
	Small seeds	Large Seeds
S	0.48 <sup>bc</sup>	0.41 <sup>c</sup>
CS	0.61 <sup>a</sup>	0.50 <sup>bc</sup>
CSC	0.59 <sup>ab</sup>	0.57 <sup>ab</sup>
No-till	0.48 <sup>bc</sup>	0.55 <sup>ab</sup>

# Means with the same letter are not significantly different at P>0.05

**Table 1.4:** The emergence percentage of *Digitaria eriantha* using different seedbed preparations (Dannhauser 1985).

Clay %	Seedbed consolidation after planting	Germination after 28 days (%)	Germination after 63 days (%)
7.7	Rolled	11.3	46.6 <sup>a</sup>
	Not rolled	0	46.7 <sup>a</sup>
31.4	Rolled	78.0	78.0 <sup>A</sup>
	Not rolled	58.0	72.0 <sup>A</sup>

# Means with the same letter are not significantly different at P>0.05

Dannhauser (1985) evaluated the effect of consolidating a seedbed of soils with differing clay percentages, after establishing *D. eriantha* (Table 1.4). For the first 28 days after planting, the soil water was kept at field capacity. From day 28 to 63, the soil was allowed to dry and then irrigated again. The results indicate that the effect of consolidating the seedbed post-planting has a positive effect on establishment of *D.*

*eriantha* at 28 days, even though no significant differences were observed at 63 days.

## Species selection

Tropical and subtropical grass species grow actively during summer but will become dormant during winter because of low temperatures and moisture stress in summer rainfall areas (Dannhauser 1991). During the growing season, all these grasses can be grazed. Some species have alternative uses like foggage, hay, silage and erosion control. Three subtropical grass species commonly cultivated in South Africa are *Chloris gayana* (var. Katambora), *Eragrostis curvula* (var. Ermelo) and *Digitaria eriantha* (var. Irene) (Dannhauser 1991, Van Oudtshoorn 1999).

*Chloris gayana* (Rhodes grass) was promoted as a pasture species by Cecil John Rhodes in South Africa in the late 1800's and early 1900's (Tainton et al. 1976, Van Oudtshoorn 1999). This weak perennial is often unfavourable in a farming system due to its poor persistence. This property can, however, be seen as a valuable attribute as to why *C. gayana* must be a pasture of choice. The poor perennial feature makes it very easy and quick to establish, and it comes into production quickly and is proving useful in a rotational cropping system as it is easily eradicated from a land (Tainton et al. 1976). This species is an ideal crop to use in the management of soil erosion or where soil needs to be stabilized (Van Oudtshoorn 1999). *Chloris gayana* is very palatable, which contributes to an even lower persistence under grazing systems than where the pasture is harvested for hay (Tainton et al. 1976).

*Eragrostis curvula* (Weeping love grass) is a very common planted pasture species used in South Africa for grazing or as a hay crop (Pasture Handbook 2007). It is the most important planted pasture species in the cooler parts of South Africa (Van Oudtshoorn 1999). There are a couple of *E. curvula* varieties available in South Africa. Generally, Ermelo is the variety most widely cultivated (Pasture Handbook 2007). Although it is a strong perennial, it establishes relatively easily and quickly and produces its first forage soon after planting (Tainton et al. 1976, Van Oudtshoorn 1999). Its true value lies in its longer growing season. The early spring growth in particular, is a desired property and it produces forage earlier than most other

summer growers (Tainton et al. 1976). *Eragrostis curvula* is less acceptable to grazing animals, but its good drying ability ensures top quality hay. Quality and palatability is, however, dependent on fertility of the soil and can be manipulated through adaptive management (Tainton et al. 1976).

*Digitaria eriantha* (Smutsfinger grass) is another strong perennial species; nevertheless, it establishes very slowly (Tainton et al. 1976). The quality foggage it produces is exceptional. Nutritive value of this species remains high well into mid-winter (Tainton et al. 1976, Van Oudtshoorn 1999). It is furthermore adapted to a wide range of soils (Van Oudtshoorn 1999) and environments, drought resistant and tolerant to high grazing pressure for short periods. It has a rather fine seed with an awn and it is important not to plant deeper than 10 mm (Moore et al. 2006). The attributes of these subtropical species makes the production of one or more valuable to the fodder flow programme by increasing the fodder production per area.

## **Conclusion**

From a scientific point of view, there are multiple factors to consider for optimum pasture establishment. These include sufficient water and oxygen, the optimum temperature and ideal physical environment. Pre-establishment techniques like seed treatments, seeding rates, nurse crops, seedbed preparation and –consolidation can all have direct or indirect effects on the factors affecting establishment. Some of these pre-establishment techniques have shown to improve establishment. Literature cited for this study, provided no evidence that a combination of treatments will affect the individual effect of a treatment. The success of some individual techniques or combinations of them, on different pasture species, is therefore not properly researched.

## **Problem Statement**

There are various physiological processes required to successfully establish perennial subtropical pastures. These include: (i) inter- and intra-species competition as influenced by pre-establishment variables such as seed rate adjustment and/or nurse crop association. (ii) Specific environmental seed conditioning as influenced by

other pre-establishment variables such as seed treatments and/or seedbed preparation. Consequently the problem statement is that the value of these pre-establishment techniques is not always understood by the farmer and therefore not recognized since little information exists on the significance thereof. Furthermore, the interactions between these techniques are also unknown.

## Hypotheses

- i. Nurse crops will improve pasture establishment.
- ii. Seeding rates are influenced by other pre-establishment techniques.
- iii. Coated seed will perform better than uncoated seed.
- iv. Finer and firmer seedbeds ensure better seed-soil contact thereby ensuring better germination.
- v. The interactions between pre-establishment techniques will influence effectiveness of individual pre-establishment techniques.

## Research Aim and Objectives

The aim of this study is to establish if there is any correlation between pre-establishment techniques and establishment success. The objectives of this study are to:

- i. Establish whether a nurse crop will facilitate better establishment.
- ii. Determine how seeding rate affects establishment success.
- iii. Establish whether seed treatments have an effect on establishment.
- iv. Determine the effect of seedbed quality on the germination of seeds and subsequently pasture establishment.

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## CHAPTER 2

Prepared according to the guidelines of African Journal of Range and Forage Science

### **The effect of pre-establishment techniques on the establishment and growth of three subtropical species in a controlled environment**

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#### **Abstract**

*Eragrostis curvula*, *Digitaria eriantha* and *Chloris gayana* are commonly cultivated subtropical grass species in South Africa. The production potential of a pasture is determined by its successful establishment. The experiments were conducted in a controlled environment. The *D. eriantha* and *C. gayana* were only evaluated as uncoated and coated (conventionally- and Mycortex coated) seed. *Eragrostis curvula* was measured as uncoated and conventionally coated seed and was also evaluated at different seeding rates (weight basis) [80% of selected seeding rate (5.6 kg.ha<sup>-1</sup>), selected seeding rate (7 kg.ha<sup>-1</sup>) and 120% selected seeding rate (8.4 kg.ha<sup>-1</sup>)], planted with and without an annual nurse crop (*Eragrostis tef*) and where seedbed consolidation was done after planting. The treatments were replicated between three and six times in four experiments. It was established that coated seed does not significantly improve establishment of any of the relevant species. Adapting the *E. curvula* seeding rate had no significant effect because of the favourable environment in which the experiment was conducted. Consolidating the seedbed caused a significantly lower emergence and yield of *E. curvula* as a result of an anaerobic condition being created around the seed. The nurse crop planted with *E. curvula* caused an increased yield in the first season. Pre-establishment techniques applied as treatments in these experiments were not effective in a controlled environment. It is noted that different treatments influence each other's function. More detailed investigation is required.

**Keywords:** Coated seed, nurse crop, *Eragrostis curvula*, *Digitaria eriantha*, *Chloris gayana*.

## Introduction

The human population of South Africa is increasing exponentially, while the land available for beef or mutton production does not allow these enterprises to grow according to the growing demand (Aucamp 2000). Arable land is becoming scarcer and livestock farmers have to farm more intensively and scientifically in order to keep up with this ever growing demand (Bartholomew 2000).

Long before any planted pasture can be utilized, it first has to be successfully established (Dannhauser 1991). Seed germination- and seedling establishment stages are where the plant is the most defenceless against environmental factors (Hadas 2004).

Climatic conditions like rainfall, soil- and air temperature, solar radiation and insect predation or disease will have an impact on plant performance (Caldwell and Weber 1970 as cited by Thies et al. 1991). However, if the environmental conditions are favourable with respect to temperature, moisture and sowing depth and when seed dormancy is not an influencing factor, seeds can hypothetically germinate within two to three days of planting (Hacker 1999).

The following four abiotic factors can have an influence on seed germination and seedling establishment in the soil environment: (i) water, (ii) oxygen, (iii) temperature and (iv) mechanical impedance (Hadas 2004). These requirements of grass pastures can be met by planting in soil with good chemical and physical properties. A well prepared seedbed is essential for establishment of any pasture species (Dannhauser and De Beer 1987, Dannhauser 1991, Bartholomew 2000). Three characteristics that are needed for a good seedbed are: (i) fineness and firmness (to ensure good seed-soil contact), (ii) evenness and smoothness (for precise placement of seeds at the right depth) and (iii) a weed-free area as far as possible (to avoid competition with aggressive weed seedlings) (Dannhauser 1991, Macdonald 2005). In addition to the abiotic factors affecting establishment; biotic factors such as endo-mycorrhizal fungi can also determine the success with which seedlings establish and grow. Endo-mycorrhizas can form symbiotic associations with most plants. Arbuscules grow into the host plant's root cells through which nutrient exchange can take place between the plant and fungi (Miyasaka et al.

2003). Pre-establishment techniques can be described as seed- and soil preparation techniques that are applied to either directly or indirectly manipulate these factors and thereby ensuring the successful establishment of highly productive and stable pastures (Aucamp 2000).

The pre-establishment techniques used to improve the success with which pastures are established include the treatment or coating of seed (Copeland and McDonald 2001, Heritage Seeds 2011), adjusting the seeding rate (Lemus 2008, Bartholomew 2000), controlling seedbed quality (Douglast Koppi 1997, Atkinson et al. 2009), seedbed consolidation (Dannhauser 1991, Couture et al. 2004) and planting nurse crops (Dannhauser 1991, Bartholomew 2000) to facilitate better establishment.

Pre-establishment technique such as seed coating is a possible method to overcome the vulnerability of the perennial pasture during establishment as a result of small seed and unknown seedling vigour (Heritage Seeds 2011). Seed coating is a process of applying layers of substances such as pesticides, growth stimulators, dormancy-breaking substances, limestone, micronutrients and even macronutrients without drastically changing the shape of the seed (Copeland and McDonald 2001, Heritage Seeds 2011). Additionally, seeds can be coated with a Mycortex S coating. The Mycortex S coating is made up of endo-mycorrhizas in spore form and bio stimulants that are beneficial to endo-mycorrhiza growth and prevents other fungal infections (Biotechnica 2011).

Seeding rates can be altered according to the species planted, different planting methods and also the quality of the seed used. If poor quality seed is used it is advisable to increase the seeding rate to compensate for the expected lower germination potential (Lemus 2008). According to Bartholomew (2000) the seeding rate can be adapted because of the following reasons: (i) purity, (ii) germination percentage, (iii) seed size, (iv) seed weight, (v) soil fertility and soil moisture, (vi) seedbed quality, (vii) sowing method, (viii) pasture purpose and (ix) perenniality of pasture.

Whenever a farmer wants to establish a perennial species, and has the immediate need of forage, an annual nurse crop like *Eragrostis tef* can be planted with the perennial to ensure available forage in the first season (Dannhauser 1991, Bartholomew 2000). To achieve the desired seedbed, a tillage implement, such as a rotavator, can be used with fewer tillage actions to provide the seedbed, as opposed

to using other methods like harrowing (Marenya 2009). Power harrowing can result in a fine seedbed and subsequently better seed-soil contact (Atkinson et al. 2009) while rotary harrowing can ensure a more consistent seedbed (Douglast Koppi 1997, Atkinson et al. 2009). In forage crop production it is a common practice to roll or consolidate (lightly compact) the seedbed before and/or after planting to improve seed-soil contact and improve seedbed firmness (Dannhauser 1991, Couture et al. 2004).

Various perennial, subtropical grass species are commercially available in South Africa. Tropical and subtropical grass species grow actively during summer but will become dormant during winter (Dannhauser 1991). During the growing season (summer), most of these grasses can be grazed. Some species however, have better foggage, hay, silage and alternative uses (such as erosion control) than others. The three subtropical grass species evaluated in this experiment, which are commonly cultivated in South Africa, include *Chloris gayana* (var. Katambora), *Eragrostis curvula* (var. Ermelo) and *Digitaria eriantha* (var. Irene) (Dannhauser 1991, Van Oudtshoorn 1999).

Broadcast seeding of pastures is a common practice used to establish pastures. This method is, however, more successful in high rainfall areas (Dannhauser 1991). For optimum subtropical grass pasture production, soil pH (KCl) > 5 - [pH (H<sub>2</sub>O) > 6], soil phosphorous (P) levels must be at least 30 mg.kg<sup>-1</sup> and potassium (K) levels at least 130 mg.kg<sup>-1</sup> (Pasture Handbook 2007, FSSA 2013).

The aim of this study was to determine whether pre-establishment techniques such as seed coating, seeding rates (weight basis), nurse crop and seedbed preparation and –consolidation can influence the establishment success and subsequent production of selected grass species. This study was conducted under controlled environmental conditions to control growth factors, such as moisture and temperature. It is therefore hypothesized that favourable growth conditions created in a controlled environment reduce the function of pre-establishment techniques.

## Materials & Methods

### **Study site**

This experiment was conducted under controlled environmental conditions in a Phytotron, at the Hatfield Experimental Farm at the University of Pretoria. Environmental factors such as temperature, moisture application and soil fertility were controlled. The soil used in this study, in five kilogram plastic containers, had a clay percentage of 24.0%, pH - 6.1 (H<sub>2</sub>O), phosphorous (P) – 27.5 mg.kg<sup>-1</sup>, potassium (K) – 28 mg.kg<sup>-1</sup>, calcium (Ca) – 363 mg.kg<sup>-1</sup>, magnesium (Mg) – 93 mg.kg<sup>-1</sup>, carbon (C) – 0.65 %.

### **General experimental procedures**

*The following experimental procedures were applied to all experiments:*

Four experiments were performed in containers using; *C. gayana* (var. Katambora), *E. curvula* (var. Ermelo) and *D. eriantha* (var. Irene). The planting procedures for all four experiments were alike, except where specified. Containers were filled with five kg sieved, well mixed soil with no unwanted material. The soil P and K levels were corrected to 30 and 120 mg.kg<sup>-1</sup> soil respectively. Fifty kg N.ha<sup>-1</sup> was applied at planting. Limestone ammonium nitrate (LAN), potassium chloride (KCl) and super phosphate (Super P) (fertilizers used in this experiment) are conventionally applied as pellets but for the sake of a controlled experiment (where very little fertilizer is applied) the pellets were grinded to a powder form. Super P and KCl powder were mixed deep into the soil while the LAN was only applied as a surface fertilizer.

Containers were watered to maintain field capacity after the fertilizer was applied. The number of seeds planted was evenly distributed over the soil surface. None of the seeds were placed closer than 30 mm to the edge of the pot. Eighty milliliters of dry soil was sprinkled over the seeds to cover them with 8–10 mm soil. The soil was then consolidated to ensure good seed-soil contact and allow capillary movement of water to the surface. Transparent plastic bags were placed over the containers to avoid moisture loss and prevent crust formation. Sixty hours after planting, the first seedlings emerged, after which the bags were removed from the containers.

All unwanted seedlings that emerged were removed at day three and every day throughout the duration of the experiment. The parameters measured in these studies were total dry matter (DM) yield and the number of established seedlings. The test plants were harvested at 70 mm above soil surface when the reproductive stage commenced. The harvested plant material was dried at 60°C for 72 hours (Abate et al. 1981) and weighed. Dry plant material was weighed in grams up to two decimals.

All containers in the four experiments were watered, using a hand sprinkler, to maintain field capacity. After each harvest, nitrogen (N) topdressing was applied at a rate of 75 kg N.ha<sup>-1</sup> as LAN.

### ***Eragrostis curvula* experiment 1**

A total number of 36 containers were used in this experiment. Each treatment was replicated three times. The experimental design is summarized in Table 2.2. Treatments included:

i. **Coated or uncoated seed:** Conventionally coated and uncoated seed from the same seed batch was provided by a reputable and registered seed company.

ii. **Three seeding rates used:** A seeding rate of 7 kg.ha<sup>-1</sup> was selected for *E. curvula* as this is the current commercial recommendation (Pasture Handbook 2007). This seeding rate was adapted to 80% (5.6 kg.ha<sup>-1</sup>) and 120% (8.4 kg.ha<sup>-1</sup>) the selected seeding rate, respectively, to evaluate a lower and higher seeding rate than the recommend 7 kg.ha<sup>-1</sup>. The selected seeding rate for coated and uncoated seed was the same on a weight basis. The coating substance will, however, substitute seed in the case of coated seed. The substitution on this batch of *E. curvula* occurred at a ratio of 1:2.2, which explains that the uncoated seed was 2.2 times more in numbers than the coated seed, when the same weight of seed was planted. Seeds for different seeding rates were weighed and counted for coated and uncoated treatments, respectively. The seeding rates were weighed and thereafter counted to ensure that the exact same number of seeds is planted in every seeding rate category of all treatment replications (Table 2.1).

iii. **Nurse crop:** *Eragrostis tef* was planted at a fixed recommended seeding rate of 5 kg.ha<sup>-1</sup> to serve as a nurse crop. This is the lowest rate

recommended by Dannhauser (1991). *Eragrostis tef* seeds were planted in half the number of containers as opposed to no nurse crop in others.



**Figure 2.1:** *Eragrostis tef* planted as a nurse crop (container on the left) as opposed to no nurse crop (container on the right).

**Table 2.1:** The number of seeds planted in every seeding rate treatment.

Type of seed	Number of seeds planted in each pot at different seeding rates		
	80%	100%	120%
<i>E. curvula</i> (uncoated)	44	58	65
<i>E. curvula</i> (coated)	21	28	34
<i>E. tef</i> (if applicable)	64	64	64

**Table 2.2:** *Eragrostis curvula* (1) experimental treatments (Summary).

Treatment	Factor by which the experimental units increase	Description
Coated	2	• <i>E. curvula</i> (coated or uncoated)
Nurse crop	2	• <i>E. tef</i> (as nurse crop or not)
Seeding rates	3	• 80%, 100% and 120% of a selected seeding rate
Replications	3	

### ***Experimental procedure***

No thinning of *Eragrostis* species was done. All the *Eragrostis* plants that emerged, established and survived were left to grow. Throughout the experiment, soil was kept at field capacity. The experiment and layout was a Randomized Complete Block Design (RCBD). The statistical program GenStat® (Payne et al. 2012a) was used for the data analysis. Fisher's protected least significant difference test was used at the 5% level.

### ***Eragrostis curvula experiment 2***

A second *E. curvula* experiment was conducted to account for the unknown number of plants measured in *Eragrostis curvula* experiment 1. A total number of 24 containers were used in this experiment. There were six replications for each treatment. The experimental design is summarized in Table 2.3. Treatments applied include:

i. **Coated or uncoated seed:** Coated and uncoated seed from the same seed batch was provided by a reputable and registered seed company.

ii. **Seedbed consolidation after planting:** In an attempt to simulate the rolling effect after planting in the field, the soil was consolidated after planting in the container. This was done in all other container experiments, but was applied as a treatment in this experiment.

**Table 2.3:** *Eragrostis curvula* (2) experimental treatments (Summary).

Treatment	Factor by which the experimental units increase	Description
Coated	2	<ul style="list-style-type: none"> <li>• <i>E. curvula</i> was coated or uncoated</li> </ul>
Seedbed consolidation	2	<ul style="list-style-type: none"> <li>• Consolidating the seedbed vs. no consolidation</li> </ul>
Replications	6	

### ***Experimental procedures***

Only ten seeds were planted per container. To account for an unknown delay in germination rate between coated and uncoated seed, seedling count only commenced at day 16 followed by subsequent five day intervals. Seedlings were then thinned to two plants per container. Thereafter three harvestings were collected at the 10% flowering stage and dry matter yield (g.container<sup>-1</sup>) determined.

The experiment layout was a RCBD. The statistical program GenStat® (Payne et al. 2012a) was used for the data analysis. Linear Mixed Model analysis, also known as REML analysis (Payne et al. 2012b), was applied to seed counts to model the correlation over 26 days in an analysis of repeated measurements. The fixed effects were specified as day, coated and consolidated treatments and all the interactions, while the random effect was specified as the plot by day interaction, also accounting for heterogeneous treatment variances. An ante dependence model of order 1 (ANT1) was found to best model the correlation over days. Fisher's protected least significant difference test was used at the 5% level.

### ***Chloris gayana- and Digitaria eriantha experiment***

In the interest of understanding whether the hypothesis is relevant for other species this small experiment was conducted for the seed coating treatment, since this pre-establishment technique has a direct effect on the seed itself. This trial only focused on the coating treatment on *C. gayana* and *D. eriantha*. A total number of 15

containers were used for each of these species. There were five replications of each treatment. The experimental design is summarized in Table 2.4. Treatments applied include:

i. **Coated, Mycortex (product name - Mycortex S) coated and uncoated seeds.** Coated (conventional and Mycortex) and uncoated seed from the same seed batch was provided by a reputable and registered seed company.

**Table 2.4:** *Chloris gayana*- and *Digitaria eriantha* experimental treatments (Summary).

Treatment	Factor by which the experimental units increase	Description
Coated	3	• Coated vs. Mycortex coated vs. uncoated
Replications	5	

### ***Experimental procedures***

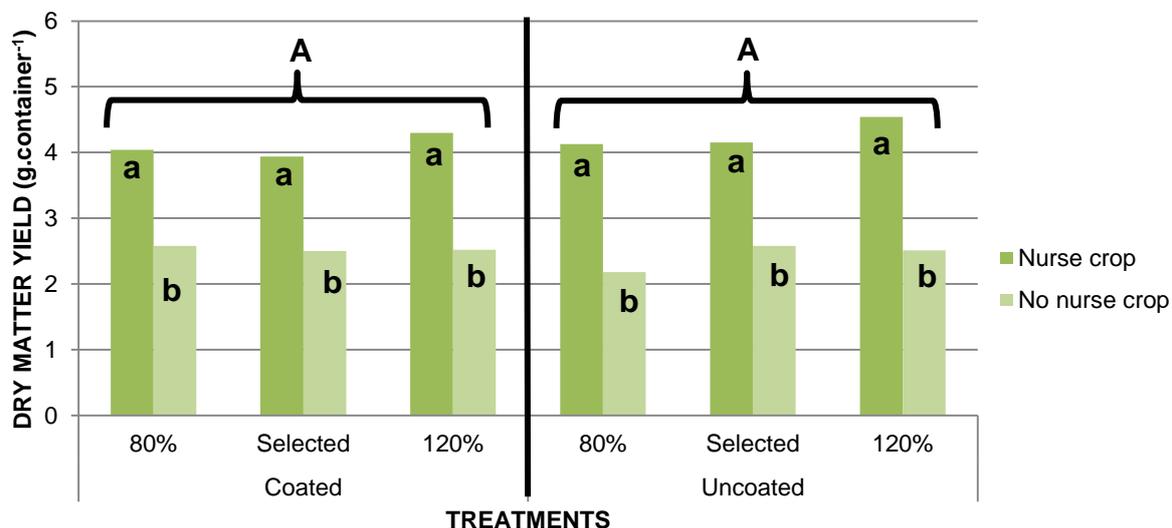
Ten seeds were planted per container and after 14 days seedlings were thinned out. Thinning was done depending on the number of plants that emerged per container. Plants were thinned to the same number that emerged in the container with the least number of seedlings. *Chloris gayana* experiment was thinned to two plants per container and *Digitaria eriantha* experiment was thinned to one plant per container. After thinning, plants were left to grow out and three harvestings were attained for each species and dried to get the DM production.

The experiment layout was a RCBD. The statistical program GenStat® (Payne et al. 2012a) was used for the data analysis. Fisher's protected least significant difference test was used at the 5% level.

## Results and Discussion

### *Eragrostis curvula* experiment 1

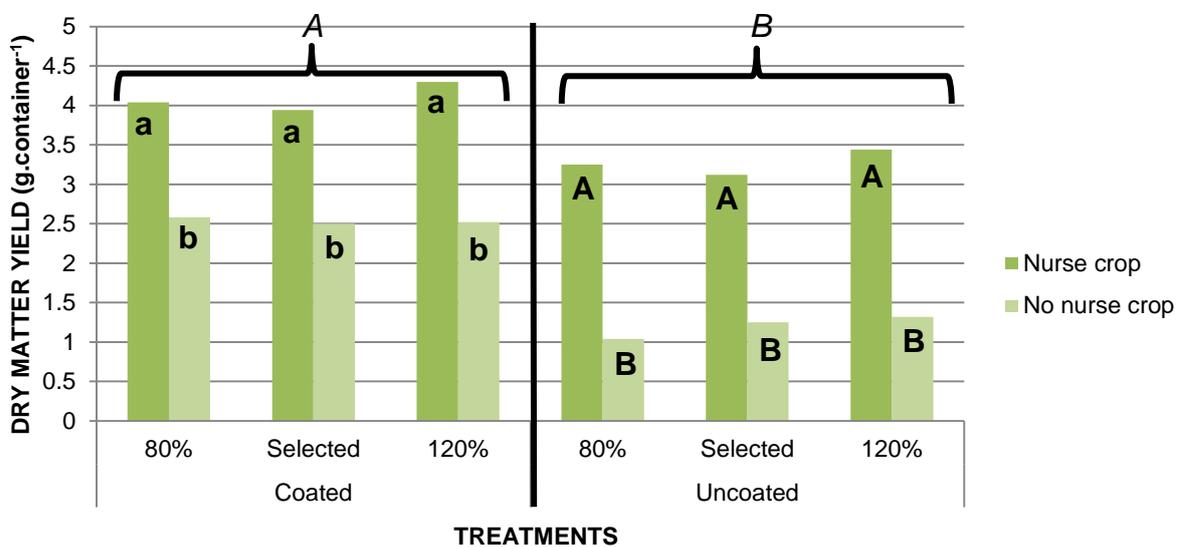
It has to be kept in mind that the coated and uncoated seed were planted at the same seeding rate on a basis of weight in *Eragrostis curvula* experiment 1. One coated seed weighs 2.2 times more than one uncoated seed. The data will be presented as it was recorded and then as corrected data for the number of seeds sown. In Figure 2.2 it is apparent that the DM yield for coated and uncoated seed treatments did not differ significantly from one another. This is, however, deceitful since 2.2 times more uncoated seed was planted to achieve the insignificantly comparable yield produced from coated seed. This may be as a result of an improved establishment and/or growth facilitated by the coating. It can also be attributed to the abundant availability of water and nutrients in the controlled environment making conditions perfect for germination, emergence and establishment and growth. The data shown in Figure 2.2 also illustrates no significant differences at different seeding rates. The limited space and favourable growing environment in the container resulted in the maximum capacity of the species planted being reached at all seeding rates in each container.



**Figure 2.2:** The interactive influence of seed coating, nurse crop and seeding rate (weight basis) on DM yield of *E. curvula*.

# Means with the same letter are not significantly different at  $P > 0.05$

There was a slight increase in DM yield.container<sup>-1</sup> from the selected seeding rate to the 120% seeding rate. This was however not statistically or practically significant ( $P > 0.1$ ) (Figure 2.2). The use of a nurse crop had a significant increase in DM yield.container<sup>-1</sup> (Figure 2.2). This is understandable as the *E. tef*, that was used as a nurse crop is an annual plant, and establishes easily and grows fast. The maximum growth capacity in the containers was reached with some of the *E. curvula* plants being replaced with faster growing *E. tef*. In Figure 2.3 it can be seen that where the data is corrected for the number of seeds planted, the coated seed had significantly higher yields per seed planted. There were 2.3 times more uncoated seed planted, and therefore, the yield per seed planted were lower.



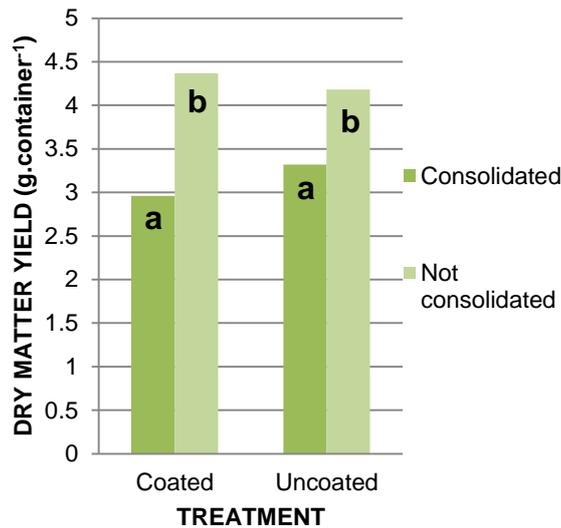
**Figure 2.3:** The interactive influence of seed coating, nurse crop and seeding rate (weight basis) on DM yield of *E. curvula* (corrected for number of seeds planted).

# Means with the same letter are not significantly different at  $P > 0.05$

### ***Eragrostis curvula* experiment 2**

Where this study focused on growing the same number of plants per container, there was still no significant differences observed between DM yield from coated and uncoated seed (Figure 2.4). The aim of consolidating the seedbed was to improve seed-soil contact and therefore increase the seed surface accessible to soil moisture. In a controlled environment such as a Phytotron, there was nevertheless an abundance of moisture available to the seed. The results obtained from applying this treatment was contradictory to literature and can possibly be ascribed to an

anaerobic soil condition created by the consolidation of wet soil. This condition was aggravated more by covering the containers with plastic bags, a technique implemented to reduce excessive evaporation. The DM yield.pot<sup>-1</sup> was significantly higher where no consolidation took place (Figure 2.4). This phenomenon is due to an earlier emergence where no consolidation of soil was done. This resulted in more mature plants by the time harvesting commenced.

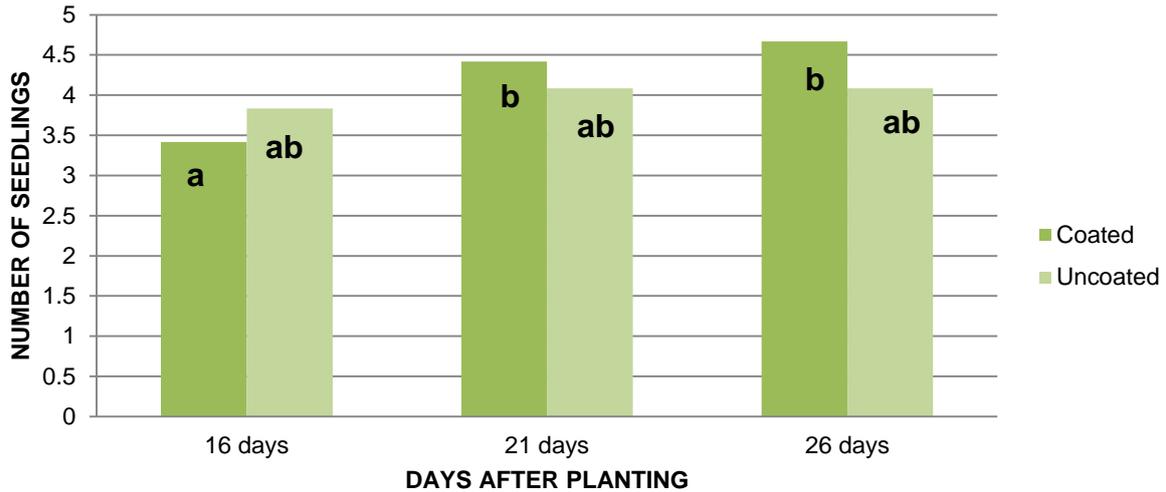


**Figure 2.4:** The interactive influence of seed coating and seedbed consolidation on DM yield of *E. curvula*.

# Means with the same letter are not significantly different at P>0.05

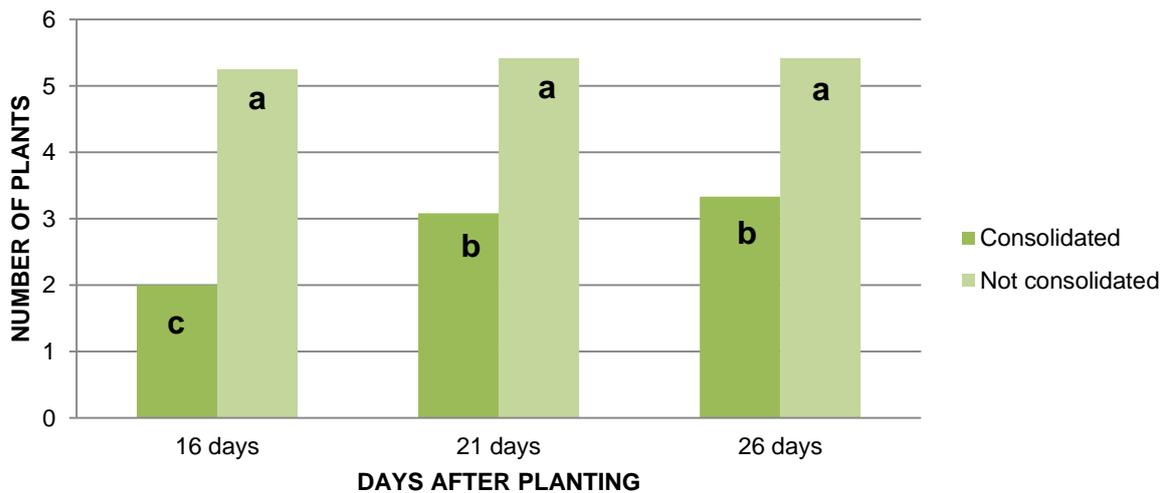
In Figure 2.5 the number of seedlings counted at 16, 21 and 26 days after planting is presented. At no stage was there a significant difference between coated and uncoated seed. The number of emerged plants was significantly different for coated seed between 16 and 21, 26 days after planting (Figure 2.5). The coated seed tended to germinate and establish slower than uncoated seed due to the coating substance forming an obstruction for water penetration. Eventually the coated seed compensated for the slow start.

From Figure 2.6 it is clear that where the soil was not consolidated after planting, a significantly higher number of plants emerged. Where the soil however, had been consolidated a significantly higher number of plants were observed at 21 and 26 days after planting, as opposed to 16 days.



**Figure 2.5:** The influence of seed coating on the number of seedlings of *E. curvula* at three stages after planting.

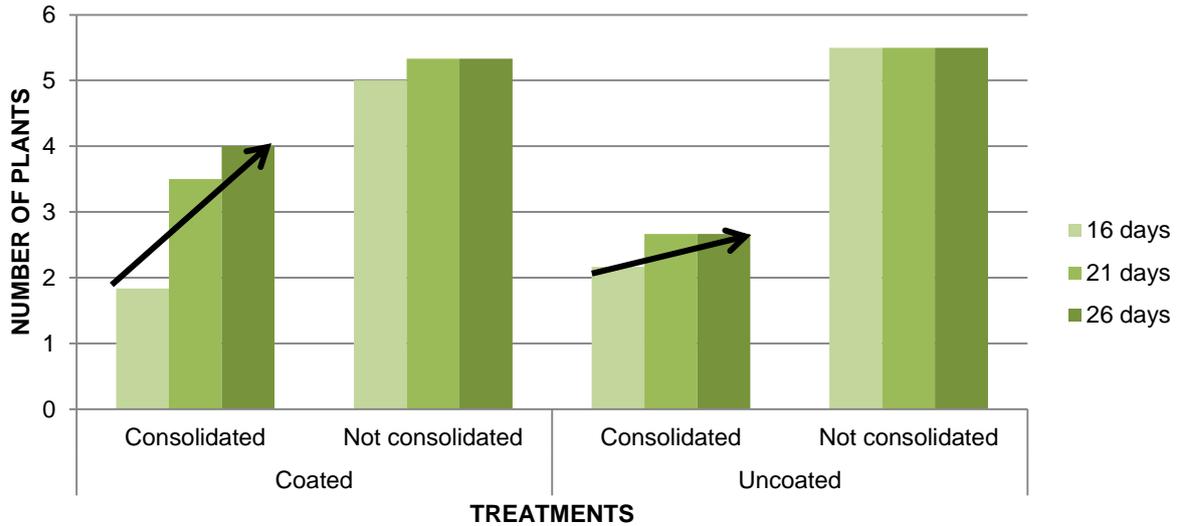
# Means with the same letter are not significantly different at  $P > 0.05$



**Figure 2.6:** The influence of seedbed consolidation on the number of seedlings of *E. curvula* at three stages after planting.

# Means with the same letter are not significantly different at  $P > 0.05$

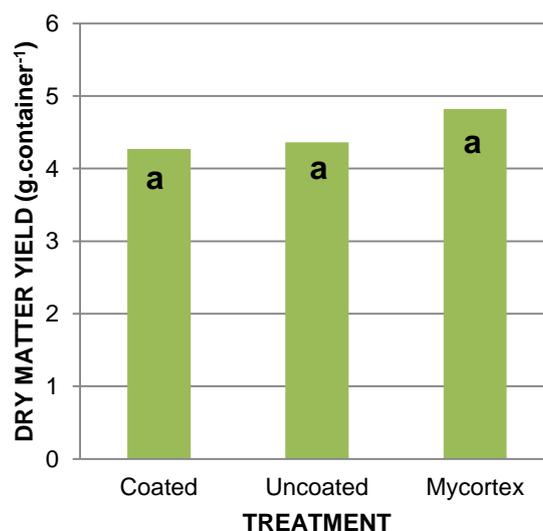
In Figure 2.7 it can be seen that, even if there was no statistically significant interactive effects observed between coated- and consolidated treatments, there was a trend that the number of emerged plants increased more so with coated seed than uncoated seed, especially over time where soil was consolidated.



**Figure 2.7:** The interactive influence of seed coating and seedbed consolidation on the number of seedlings of *E. curvula* at three stages after planting.

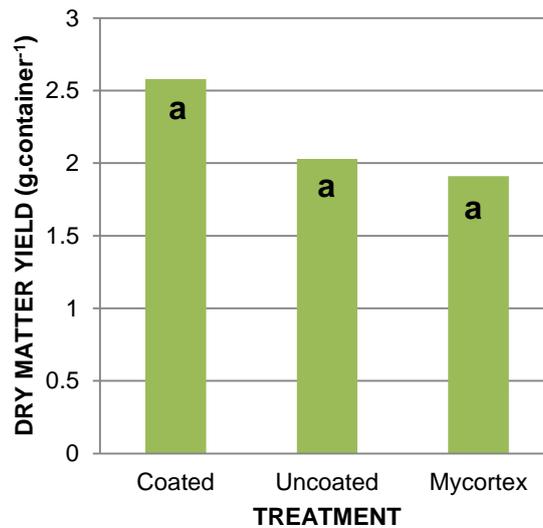
### ***Chloris gayana*- and *Digitaria eriantha* experiment**

In the *Chloris gayana*-experiment (Figure 2.8) and *Digitaria eriantha*-experiment (Figure 2.9), the DM yield.container<sup>-1</sup> showed no significant differences between the uncoated, coated and Mycortex coated seed. This can be ascribed to the abundance in nutrients, water and minimal stresses in the container. This emphasizes the value of the certain constituents in the seed coating that gave plants an advantage in an unfavourable environment.



**Figure 2.8:** The influence of seed coating on DM yield of *C. gayana*.

# Means with the same letter are not significantly different at P>0.05



**Figure 2.9:** The influence of seed coating on DM yield of *D. eriantha*.

# Means with the same letter are not significantly different at  $P > 0.05$

## Conclusions

Seed coating did not have a significant effect on the establishment or growth of selected species in a controlled environment. Coated seed resulted in a delayed germination and emergence of *E. curvula* in a controlled environment and this can be ascribed to the dissolution of the coating before germination can commence. It is recommended that future research should evaluate the emergence of seed and growth of seedlings as influenced by the coating within field conditions.

Adapting the seeding rate (weight basis; upwards or downwards) of *E. curvula* in a controlled environment, with ideal germination and growing conditions, resulted in no significant differences between DM yields. This was as a result of no competition for nutrients and moisture. However, competition for space between less or more plants existed. This was compensated for by favourable conditions and is reflected in the vigour of individual plants in variable plant densities. The findings bring forth the recommendation that the adjusted seed rates for field conditions be evaluated in terms of pasture sward density.

The purpose to create a micro-environment by planting a nurse crop (*E. tef*) together with a perennial species (*E. curvula*) in a controlled environment where growing conditions are optimal, resulted in a heightened competition effect between

species. It is essential to conduct field studies to evaluate the effect of using a nurse crop on establishment of perennial species.

Achieving the true effect of consolidation of the seedbed was not possible within the controlled environmental conditions as it was ignorantly aggravated by techniques used to prevent rapid drying of the soil. Further field studies are required to assess the value of consolidation on establishment success of perennial species.

The insignificant results from this study support the original hypothesis that favourable growing conditions reduce the functions of pre-establishment techniques, during the facilitated establishment of sown pasture seed.

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## CHAPTER 3

Prepared according to the guidelines of African Journal of Range and Forage Science

### Inter- and intra-species competition as influenced by variable seeding rates and nurse crop association

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#### Abstract

The secret of successful planted pastures lies in the execution of good pre-establishment techniques such as optimal seeding rates and nurse crop function. The current debate on the value of higher or lower seeding rates of pasture species, in addition to the inclusion of a nurse crop in production systems, raises the concern of whether significant competitive effects exist amongst plants in the sward. *Eragrostis curvula*, *Digitaria eriantha* and *Chloris gayana* are commonly cultivated subtropical grass species in South Africa and are used as test species in this field study. Replicated field experiments in a Randomized Block Design were conducted, evaluating the pasture growth response to variable seeding rate treatments (80% of selected seeding rate, selected seeding rate and 120% selected seeding rate) of uncoated and conventionally coated seed; in the case of *D. eriantha* and *C. gayana* Mycortex coated seed was also used. The experiments included the measurement of the effects of an annual nurse crop, *Eragrostis tef*, on the establishment of associated perennial grass species. It was concluded that a higher seeding rate gives a better first season plant density. However, in season two this treatment had an equal plant density as the original lower seeding rate treatments for *E. curvula* and *C. gayana*. This was as a result of intra-species competition (competition between plants of the same species) in season one, resulting in plants out competing one another. A primary function of the nurse crop planted with a perennial grass species is to minimize fierce weed competition. The establishment success of perennial species was lower, where nurse crops were included, as a result of inter-species competition (competition between plants of different species). Season two data indicates that *D. eriantha* and *C. gayana* did not have lower plant densities where a nurse

crop was planted, whereas *E. curvula* still had significantly lower plant densities. The results highlight the interactive effects between seed coatings, seeding rates and nurse crop treatments as a function of selected species.

**Keywords:** Nurse crop, seeding rate, *Eragrostis curvula*, *Digitaria eriantha*, *Chloris gayana*.

## Introduction

Veld forms an integral part of a fodder flow programme for many livestock farmers. However, more than two decades ago, Dannhauser (1991) reiterated the importance of planted pastures as a result of rapid veld deterioration. The cultivation of pasture- and more specifically grass species can replace and/or supplement veld to improve the grazing capacity of an area. This is essential for farmers using pastures as a forage source for livestock (Thompson and Poppi 1990, Dannhauser 1991, Bartholomew 2000).

Various perennial, subtropical grass species are commercially available in South Africa. Tropical and subtropical grass species grow actively during summer but will become dormant during winter (Dannhauser 1991). During the growing season (summer), most of these grasses can be grazed. The three subtropical grass species planted in this experiment, are commonly cultivated in South Africa and include *Chloris gayana* (var. Katambora), *Eragrostis curvula* (var. Ermelo) and *Digitaria eriantha* (var. Irene) (Dannhauser 1991, Van Oudtshoorn 1999).

Successful pastures with high productivity and good quality are the direct result of proper pasture establishment. Pasture establishment can be divided into the following three stages: (i) germination of seed, (ii) establishment of the seedling and (iii) the thickening up of pasture (Loch et al. 1999). Success during stages one and two is critical and it is partly determined by good pre-establishment techniques.

The techniques used to improve the success with which pastures are established include; adjusting the seeding rate (Lemus 2008, Bartholomew 2000), planting of nurse crops (Dannhauser 1991, Bartholomew 2000) to ultimately facilitate better establishment, the coating of seed (Copeland and McDonald 2001, Heritage Seeds 2011), controlling seedbed fineness (Douglast Koppi 1997, Atkinson et al. 2009) and seedbed consolidation (Dannhauser 1991, Couture et al. 2004).

According to Bartholomew (2000) the seeding rate can be adapted to compensate for the following reasons: (i) purity, (ii) germination percentage, (iii) seed size, (iv) seed weight, (v) soil fertility and soil moisture, (vi) seedbed quality, (vii) sowing method, (viii) pasture purpose and (ix) perenniality of pasture. If poor quality seed is used it is advisable to increase the seeding rate to compensate for the expected lower germination potential (Lemus 2008).

Whenever a farmer wants to establish a perennial species, and has the immediate need of forage, an annual species like *Eragrostis tef* can be planted as a nurse crop with perennial species to ensure available forage in the first season (Dannhauser 1991, Bartholomew 2000).

Seed coating is a method to overcome the vulnerability of the perennial pasture during establishment, in terms of accounting for small seed and unknown seedling vigour (Heritage Seeds 2011).

Possibly the most important practice in forage crop production is to roll or consolidate (lightly compact) the well prepared seedbed before and/or after planting to improve seed-soil contact and improve seedbed firmness (Dannhauser 1991, Couture et al. 2004).

Broadcast seeding of pastures is a common practice used to establish pastures. This method is, however, more successful in high rainfall areas (Dannhauser 1991). For optimal subtropical grass pasture production, the following requirements need to be met i.e. soil pH (KCl) > 5 - [pH (H<sub>2</sub>O) > 6], soil phosphorous (P) levels must be at least 20 mg.kg<sup>-1</sup> and potassium (K) levels at least 130 mg.kg<sup>-1</sup> (Pasture Handbook 2007, FSSA 2013).

The aim of this study is to determine whether (i) adjusting the seeding rate and/or (ii) using a nurse crop, has any significant effect on the establishment success of the test grass species. It is therefore hypothesized that adjusting the seeding rate of the perennial species and the use of a nurse crop will have significant effects on the establishment success of the perennial species.

## Materials & Methods

### **Study site**

An experimental site was selected at the field experimental section of the University of Pretoria's Experimental farm in Hatfield, Pretoria. The three experiments in this study were conducted under dry land conditions, with supplemental irrigation when it was required to prevent stand failure. Environmental factors such as temperature, moisture, wind and soil variance was not controlled. Representative soil samples were taken from the experimental site and analysed by the University of Pretoria's Department of Plant Production and Soil Science's laboratory. The soil (Hutton – sandy clay loam) used in this study had a clay percentage of 24.0%, pH - 6.1 (H<sub>2</sub>O), phosphorous (P) – 27.5 mg.kg<sup>-1</sup>, potassium (K) – 28.0 mg.kg<sup>-1</sup>, calcium (Ca) – 363.0 mg.kg<sup>-1</sup>, magnesium (Mg) – 93.0 mg.kg<sup>-1</sup>, soil carbon (C) – 0.7 %. The experimental design was a RCBD.

### **General experimental procedures**

*The following experimental procedures were applied to all experiments:*

Three experiments were performed in the field using *C. gayana* (var. Katambora), *E. curvula* (var. Ermelo) and *D. eriantha* (var. Irene). Fertilization was conducted according to the soil analysis. During seedbed preparation, all existing plant material was removed on the experimental site and the surrounding areas. Thereafter the soil was deeply ripped using a three tine ripper. Phosphorous was applied using super phosphate (Super P) according to the soil analysis to acquire a soil P level of 30 mg.kg<sup>-1</sup> (8 kg P.ha<sup>-1</sup> was required). This was followed by discing the soil, then ploughing and discing again. Hereafter seedbed preparations were treatment specific and the treatments were allocated accordingly. Nitrogen and potassium was applied at planting (Figure 3.1) using:

- i) Limestone ammonium nitrate (LAN) – 50 kg N.ha<sup>-1</sup>.
- ii) Potassium chloride (KCl) to acquire a level of 120 mg.kg<sup>-1</sup> (343 kg K.ha<sup>-1</sup> was required).



**Figure 3.1:** Fertilizer, in the form of LAN and KCl, being applied to allocated plots.

After the fertilizer was lightly worked into the top 100 mm of the soil, the seed was broadcasted according to the specified seeding rate treatments. The nurse crop, *E. tef*, was planted in the specified plots. After sowing, consolidation of specified plots was done. The soil was irrigated with 25 mm of water immediately after planting using a sprinkler system. Experiments were harvested three times in season one and four times in season two as determined by the 10% flowering stage. For autumn planting dates, only one harvest was obtained in season one at 10% flowering stage. After each harvest 75 kg N.ha<sup>-1</sup> was applied as top-dressed fertilizer.

**Table 3.1:** Seeding rates (kg.ha<sup>-1</sup>) used for every species.

Species	80%	Selected	120%
<i>E. curvula</i>	5.6	7	8.4
<i>D. eriantha</i>	6.4	8	9.6
<i>C. gayana</i>	5.6	7	8.4

The seeding rates were selected for test species according to the current commercial recommendation (Pasture Handbook 2007). The adapted seeding rates were 20% lower- and 20 % higher (Table 3.1), than the recommend rate.

A thousand seed mass was calculated for the test species and from the results it was clear that the type of seed coating used and the species being coated both had effects on the number of seeds being planted with every kg of seed. In Table 3.2 it can be seen what the ratios of uncoated seed is to coated seed for each species.

**Table 3.2:** Ratios of seed numbers between uncoated, coated and Mycortex coated seed for the same mass of seed.

Species	Uncoated	Coated	Mycortex Coated
<i>E. curvula</i>	1	0.45	-
<i>D. eriantha</i>	1	0.21	0.20
<i>C. gayana</i>	1	0.13	0.11

### ***Eragrostis curvula* field experiment**

A total number of 144 plots (3m x 3m) were planted in this experiment (Figure 3.2).



**Figure 3.2:** The experimental units of the *Eragrostis curvula* field experiment.

The experimental design is summarized in Table 3.3. Treatments included:

**i. Rotavated and non-rotavated seedbed:** To get an even, fine and firm seedbed the whole experimental area was tilled with a clot breaking roller behind it. After the seedbed was prepared, using a disc, plough and tiller, the appropriate plots were rotavated.

**ii. Coated and uncoated seed:** Coated and uncoated seed from the same seed batch was provided by a reputable and registered seed company.

**iii. Three seeding rates used:** For the 80% seeding rate, selected seeding rate and 120% seeding rate, the coated- and uncoated seed weight was the same. The coating substance will, however, substitute seed in the case of coated seed on the basis of weight (Table 3.2).

**iv. Nurse crop:** *Eragrostis tef* was planted at a fixed recommended seeding rate of 5 kg.ha<sup>-1</sup> to serve as a nurse crop (Dannhauser 1991). Control plots were planted without a nurse crop.

**v. Rolled and non-rolled seedbed:** After planting, some plots were rolled using a Cambridge roller, while other plots were not rolled.

**Table 3.3:** *Eragrostis curvula* experimental treatments (Summary).

Treatment	Factor by which the experimental units increase	Description
Rotavated	2	<ul style="list-style-type: none"> <li>Rotavated vs. non-rotavated prior to planting</li> </ul>
Coated	2	<ul style="list-style-type: none"> <li><i>E. curvula</i> was coated or uncoated</li> </ul>
Nurse crop	2	<ul style="list-style-type: none"> <li><i>E. tef</i> used or not used as nurse crop</li> </ul>
Seeding rates	3	<ul style="list-style-type: none"> <li>80%, 100% and 120% of a selected seeding rate</li> </ul>
Rolling	2	<ul style="list-style-type: none"> <li>Rolled vs. non-rolled after planting</li> </ul>
Replications	3	

### ***Experimental procedure***

No rain was recorded at the experimental site for the first two weeks after planting. The experiment was irrigated with 75 mm of water during this period, distributed as five applications of 15 mm each. The experiment was harvested three times during the first season and four times during the second season, as determined by the 10% flowering stage. One month after planting, Basagran® (active ingredient, Bentazone) a herbicide against nutsedge and broadleaf weeds, was applied. At the start of the second season Basagran® was applied again. At the end of the first season the number of *Eragrostis* (*E. curvula* and *E. tef*) plants was counted in two, one m<sup>2</sup> quadrates in each plot. At the end of the second season the number of *E. curvula* plants was again counted using the same technique.

Data was analysed using the statistical program GenStat® (Payne et al. 2012). A split-split plot RCBD was established where the whole plots were rolled or not rolled, the sub-plots were rotavated or not rotavated. The two seed coating treatments x two nurse crop x three seeding rates = 12 factorial treatments were the sub-sub-plots assigned randomly to the sub-plots. The design was replicated three times. Analysis of variance was applied to test for significant effects of all the main effects and their interactions. The distribution and variances were tested and found to be acceptably normal and homogeneous (Bartlett's test). Treatment means were separated using Fisher's least significant difference (LSD) test at the 5% level of significance (Snedecor & Cochran 1980).

### ***Digitaria eriantha field experiment***

A total number of 108 plots (3m x 4m) were planted in this experiment. Each treatment was replicated three times. The experimental design is summarized in Table 3.4. To get an even, fine and firm seedbed the whole experiment was rotavated after the initial seedbed preparation and rolled after planting. Treatments included:

i. **Coated, Mycortex (product name - Mycortex S) coated and uncoated seed:** Treated and untreated seeds from the same batch of seed were provided by a reputable and registered seed company. Treated seed were coated with a conventional seed coating and Mycortex coating. Mycortex coated seed

contained the same substances as the conventional coating, with the added Mycortex ingredient.

**ii. Three seeding rates:** For the 80% seeding rate, selected seeding rate and 120% seeding rate the coated- and uncoated seed weight was the same (Table 3.1). The coating substance will, however, substitute seed in the case of coated seed on the basis of weight. *Digitaria eriantha* seed number ratios are indicated in Table 3.2.

**iii. Nurse crop:** *Eragrostis tef* was planted at a fixed recommended seeding rate (5 kg.ha<sup>-1</sup>) to serve as a nurse crop. This seeding rate is the lowest rate recommended by Dannhauser (1991). Some plots were planted without a nurse crop.

**iv. Two planting dates:** The experiment was planted in spring and repeated in the following autumn. There was, however, no comparison made between the two planting dates, because of variable environmental factors.

**Table 3.4:** *Digitaria eriantha* experimental treatments (Summary).

Treatment	Factor by which the experimental units increase	Description
Coated	3	<ul style="list-style-type: none"> <li><i>D. eriantha</i> was coated, Mycortex coated or uncoated</li> </ul>
Nurse crop	2	<ul style="list-style-type: none"> <li><i>E. tef</i> used or not used as nurse crop</li> </ul>
Seeding rates	3	<ul style="list-style-type: none"> <li>80%, 100% and 120% of a selected seeding rate</li> </ul>
Two planting dates	2	<ul style="list-style-type: none"> <li>Spring and autumn</li> </ul>
Replications	3	

### ***Experimental procedures***

**Spring planting date:** There was no rain recorded on the spring planting date site for the first week after planting. The experiment was irrigated with approximately 45 mm of water, as three applications of 15mm each. One month and three months after

planting, Basagran® (active ingredient, Bentazone) a herbicide against nutsedge and broadleaf weeds, was applied. At the start of the second season Basagran® was applied again. At the end of the first season the number of established *D. eriantha*, and *E. tef* plants were counted in two, one m<sup>2</sup> quadrates in each plot for the spring planting date. The spring planting date experiment was evaluated again in the same way after the second season.

*Autumn planting date:* The same process of seedbed preparation and planting was used. Glyphosate was applied twice in the summer to keep the site weed free. For the autumn planting date 25 mm was irrigated after planting, Basagran® was applied once, one month after planting. For the autumn planting date the same plant count was done but only at the end of the second season. There was no evaluation in the season of planting. To quantify plants, the pasture had to be harvested first in order to get a clear view of all plants. It was decided not to harvest newly established plants (seedlings) prior to winter.

Data was analysed using the statistical program GenStat® (Payne et al. 2012). The layout was a RCBD arranged as a three x two x three factorial experiment. Treatments included three coated seed, two nurse crop, three seeding rates, amounting to 18 treatments. The design was replicated three times for each of two planting dates. Analysis of variance was applied to test for significant effects of all the main effects and their interactions. The errors and variances were tested and found to be acceptably normal and homogeneous (Bartlett's test). Treatment means were separated using Fisher's least significant difference (LSD) test at the 5% level of significance (Snedecor & Cochran 1980).

### ***Chloris gayana* field experiment**

A total number of 108 plots (3m x 4m) were planted in this experiment. Each treatment was replicated three times. The experimental design is summarized in Table 3.5. To get an even, fine and firm seedbed the whole experiment was rotavated after the initial seedbed preparation and rolled after planting. Treatments included:

i. **Coated, Mycortex S (product name - Mycortex S) coated and uncoated seed:** Treated and untreated seeds from the same batch of seed were provided by a reputable and registered seed company. Treated seed were coated

with a conventional seed coating and Mycortex coating. Mycortex coated seed contained the same substances as the conventional coating, with the added Mycortex ingredient.

ii. **Seeding rates:** For the 80% seeding rate, selected seeding rate, and 120% seeding rate the coated- and uncoated seed weight was the same (Table 3.1). The coating substance will, however, substitute seed in the case of coated seed on the basis of weight. *Chloris gayana* seed number ratios are indicated in Table 3.2.

iii. **Nurse crop:** *Eragrostis tef* was planted at a fixed recommended seeding rate (5 kg.ha<sup>-1</sup>) to serve as a nurse crop. This seeding rate is the lowest rate recommended by Dannhauser (1991). Some plots were planted without a nurse crop.

iv. **Two planting dates:** The experiment was planted in spring and repeated in the following autumn. There will however be no comparison between the two planting dates, because of variable environmental factors.

**Table 3.5:** *Chloris gayana* experimental treatments (Summary).

Treatment	Factor by which the experimental units increase	Description
Coated	3	<ul style="list-style-type: none"> <li><i>C. gayana</i> was coated, Mycortex coated or uncoated</li> </ul>
Nurse crop	2	<ul style="list-style-type: none"> <li><i>E. tef</i> used or not used as nurse crop</li> </ul>
Seeding rates	3	<ul style="list-style-type: none"> <li>80%, 100% and 120% of a selected seeding rate</li> </ul>
Two planting dates	2	<ul style="list-style-type: none"> <li>Spring and autumn</li> </ul>
Replications	3	

### ***Experimental procedures***

*Spring planting date:* There was no rain recorded on the spring planting date site for the first week after planting. The experiment was irrigated with approximately 45 mm of water as three applications of 15mm each. One month and three months after

planting, Basagran® (active ingredient, Bentazone) a herbicide against nutsedge and broadleaf weeds, was applied. At the start of the second season Basagran® was applied again. At the end of the first season the number of established *C. gayana*, and *E. tef* plants were counted in two, one m<sup>2</sup> quadrates in each block for the spring planting date. The spring planting experiment was evaluated again in the same way after the second season.

*Autumn planting date:* The same process of preparation and planting was implemented. Glyphosate was applied twice in the summer to keep the site weed free. For the autumn planting date 25 mm was irrigated after planting and Basagran® was applied once one month after planting. For the autumn planting date the same plant count was done but only at the end of the following autumn. There was no evaluation in the season of planting. To quantify plants, the pasture had to be harvested first in order to get a clear view of all plants. It was decided not to harvest newly established plants (seedlings) prior to winter.

Data were analysed using the statistical program GenStat® (Payne et al. 2012). The layout was a RCBD arranged as a three x two x three factorial experiment. Treatments included three coated seed, two nurse crop, three seeding rates, amounting to 18 treatments. The treatments were replicated three times for each of two planting dates. Analysis of variance was applied to test for significant effects of all the main effects and their interactions. The errors and variances were tested and found to be acceptably normal and homogeneous (Bartlett's test). Treatment means were separated using Fisher's least significant difference (LSD) test at the 5% level of significance (Snedecor & Cochran 1980).

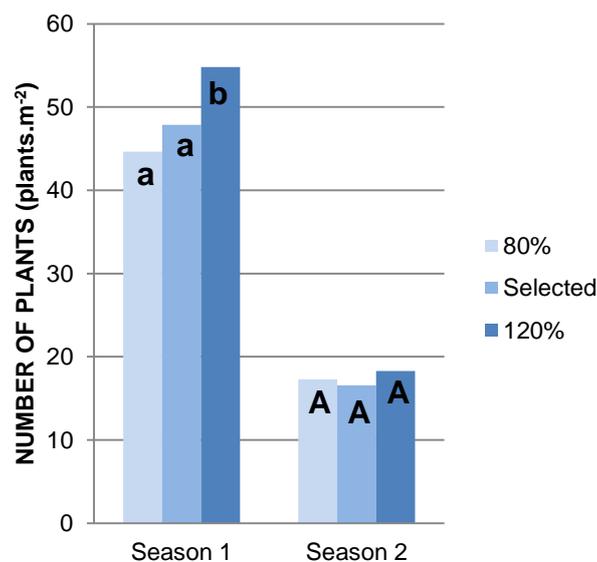
## Results and Discussion

### Seeding rate

#### *Eragrostis curvula* field experiment

*Eragrostis curvula* and *E. tef* plants were counted in the first season, since it was difficult to distinguish between the young plants of these two species. In the first season there was a significantly higher number of *Eragrostis* (*E. tef* and *E. curvula*) plants counted at the 120% seeding rate (Figure 3.3). This is attributed to a higher number of seed sown and first-season-plants still being small and uncompetitive.

In the second season, only *E. curvula* was counted. No significant differences were observed between seeding rates in season two. *Eragrostis curvula* plant numbers decreased as intra-species competition increased towards the end of first season and tufts grew larger.



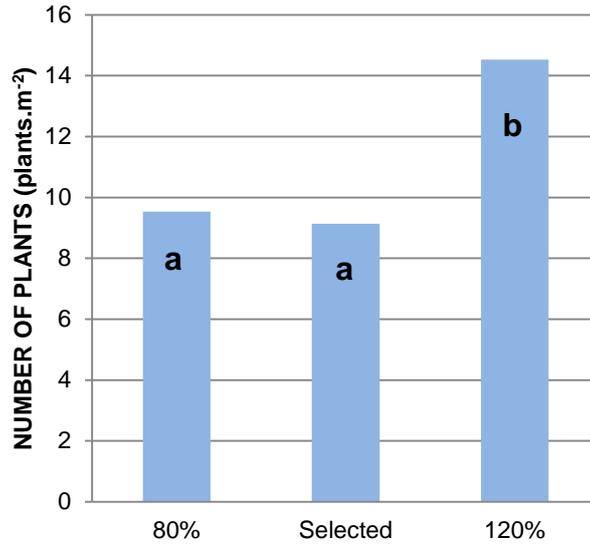
**Figure 3.3:** The number of *Eragrostis* species plants.m<sup>-2</sup> area (season one and –two) at three seeding rates.

# Means with the same letter are not significantly different at P>0.05

#### *Digitaria eriantha* field experiment

##### Spring planting date - Season 1

Since more seed is planted at a 120% seeding rate and small plants were uncompetitive in the first season, *D. eriantha* plants were significantly more in season one of the spring planting date (Figure 3.4).

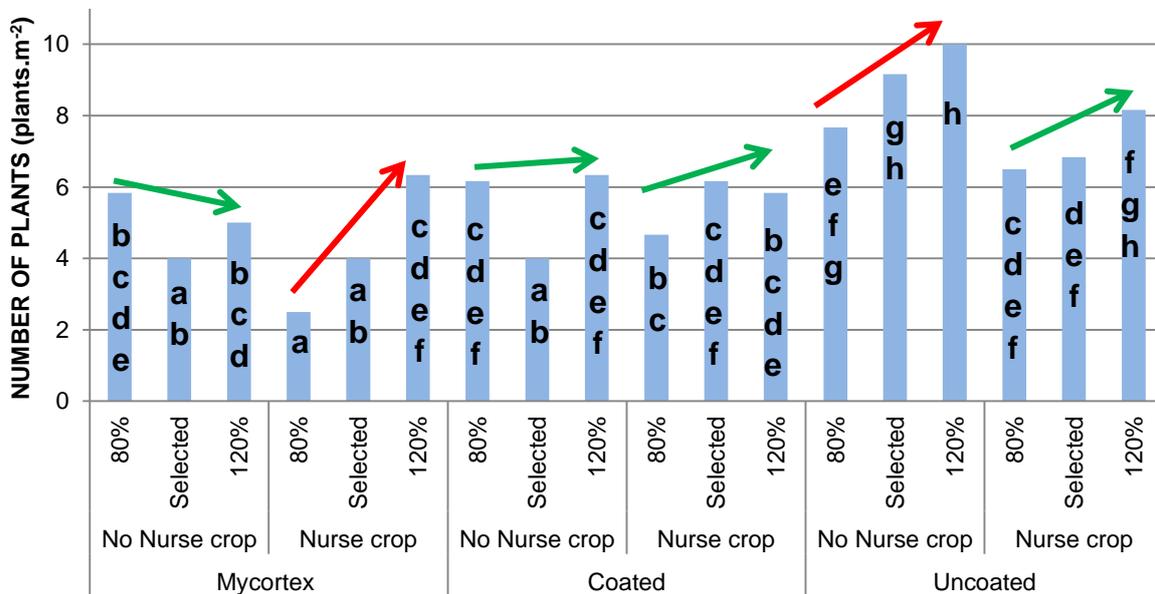


**Figure 3.4:** The number of *D. eriantha* plants.m<sup>-2</sup> area (season one, spring planting date) at three seeding rates.

# Means with the same letter are not significantly different at P>0.05

### Spring planting date - Season 2

In the second season there was an interactive effect that differed from the main effect observed.



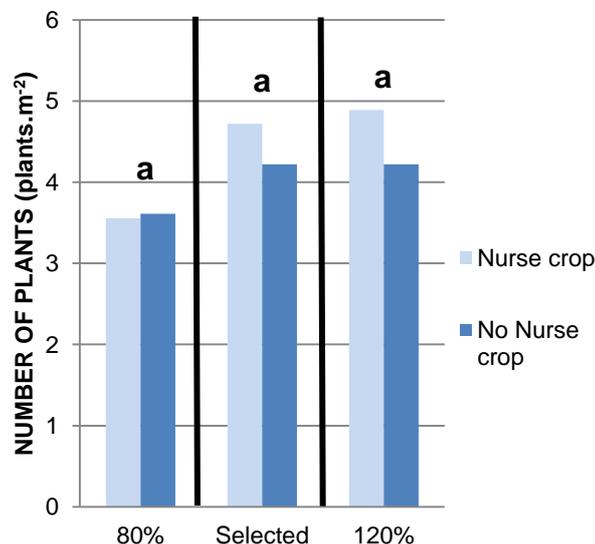
**Figure 3.5:** The number of *D. eriantha* plants.m<sup>-2</sup> area (season two, spring planting date) as influenced by the interactive effect of seeding rate (weight basis)-, nurse crop- and seed coating treatments. Red arrows indicate significant differences.

# Means with the same letter are not significantly different at P>0.1

A trend ( $P>0.1$ ) similar to season one was observed for uncoated seed planted without a nurse crop and Mycortex coated seed planted with a nurse crop (Figure 3.5). In all other cases there were no significant differences for seeding rate treatments. These insignificant differences among *D. eriantha* plants in season two occurred because an optimum plant density had been reached as a result of intra-species competition. More plants were lost at the 120% seeding rate, from season one to season two, to reach the optimum plant density. Where uncoated seed was planted without a nurse crop, the highest number of *D. eriantha* seeds (uncoated seed) was sown without competition from *E. tef*. The noted higher establishment success at 120% seeding rate was due to second season germination of seed planted in season one. Where Mycortex coated seed was planted at 80% seeding rate (weight basis), the least amount of seed was planted. It was furthermore planted with a nurse crop that created competition.

### Autumn planting date

Plants in the autumn planting date experiment were only counted in the second season.



**Figure 3.6:** The number of *D. eriantha* plants.m<sup>-2</sup> area (season two, autumn planting date) at three seeding rates with and without a nurse crop.

# Means with the same letter are not significantly different at  $P>0.05$

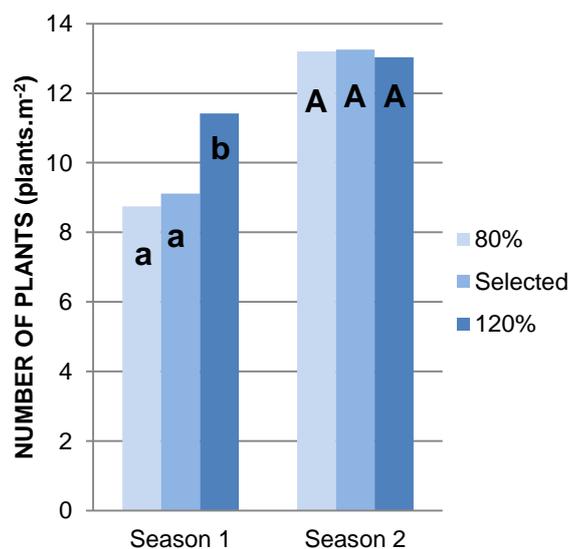
There were no significant differences noted between different seeding rates (Figure 3.6). It must be noted that there was very poor establishment with less than five

plants.m<sup>-2</sup> in all cases. However, a similar trend was noted in the spring planting date experiment.

### ***Chloris gayana* field experiment**

#### **Spring planting date - Season 1 & 2**

In season one at the 120% seeding rate, a significantly higher number of plants were counted (Figure 3.7). In season two there were no significant differences amongst treatments. Competition between tufts was not responsible for this result, but it was rather due to the creeping characteristics of *C. gayana* and its ability to spread through stolons. There were more plants counted in season two than in season one since new tufts were formed from creeping stolons, even though intra-species competition could have occurred.



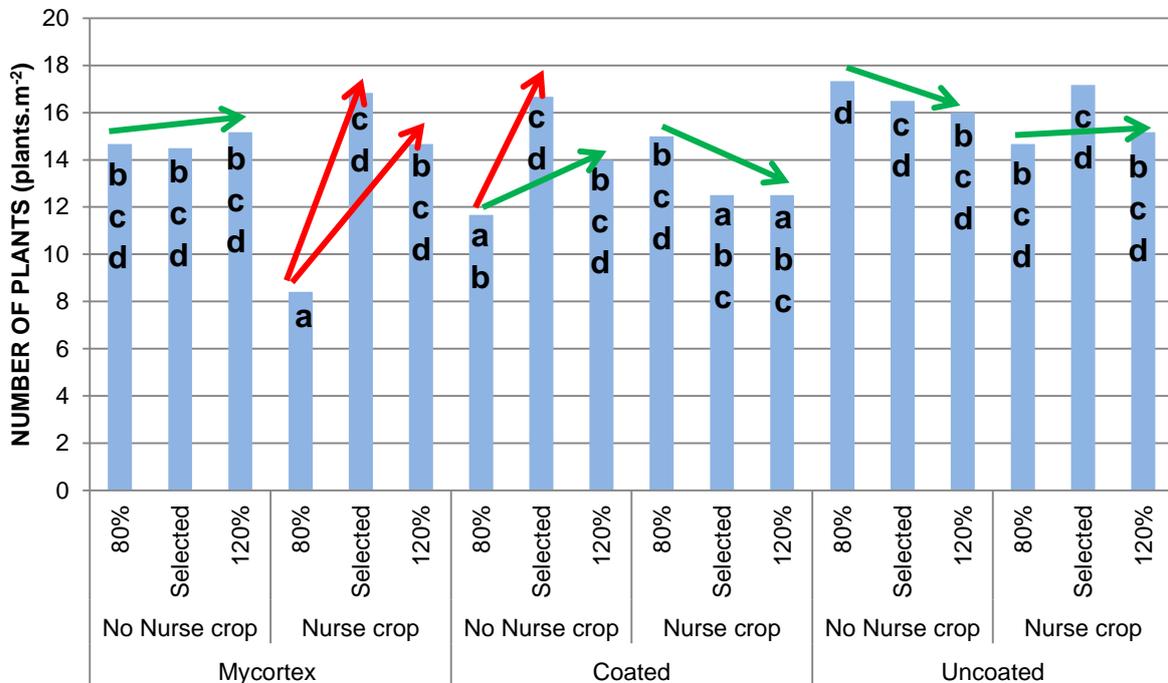
**Figure 3.7:** The number of *C. gayana* plants.m<sup>-2</sup> area (season one and -two, spring planting date) at three seeding rates.

# Means with the same letter are not significantly different at P>0.05

#### **Autumn planting date**

Plants in the autumn planting date experiment were only counted in season two. An interactive effect was seen. Mycortex and conventionally coated seed had significantly lower numbers of plants at the 80% seeding rate (weight basis; Mycortex coating with a nurse crop and conventional coating without a nurse crop). These results were obtained as a result of the lowest numbers of seed being planted

for these treatments in this experiment (Figure 3.8). Nevertheless, the conventional coating at the same seeding rate (80%) planted with a nurse crop, didn't show the same trend.



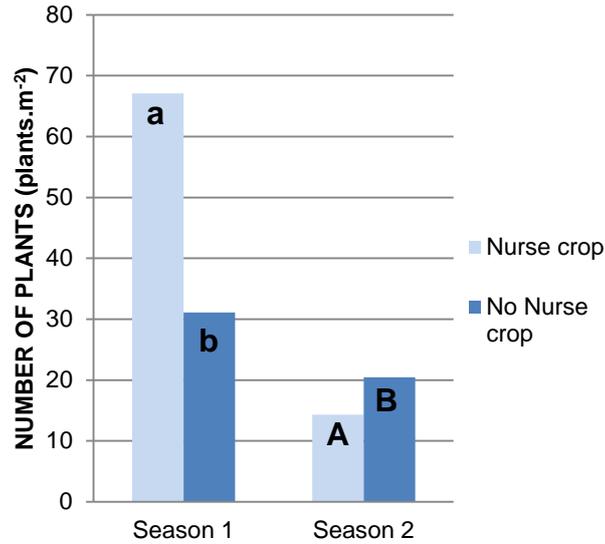
**Figure 3.8:** The number of *C. gayana* plants.m<sup>-2</sup> area (season two, autumn planting date) as influenced by the interactive effect of seeding rate (weight basis)-, seed coating- and nurse crop treatments. Red arrows indicate significant differences.

# Means with the same letter are not significantly different at P>0.05

### Nurse crop

#### *Eragrostis curvula* field experiment

It has to be kept in mind that both *E. curvula* and *E. tef* plants were counted in the first season, since it was difficult to distinguish between the young plants of these two species. In the first season there was a significantly higher number of *Eragrostis* plants counted where the nurse crop was planted. This is understandable, because *E. tef* that was planted with *E. curvula* (Figure 3.9). In the second season, only *E. curvula* was counted since it was easier to distinguish between *E. curvula* and the few new *E. tef* plants in season two. There was a significantly higher number of plants in season two where no nurse crop was planted. This was because of inter-species competition with *E. tef* in the first season.

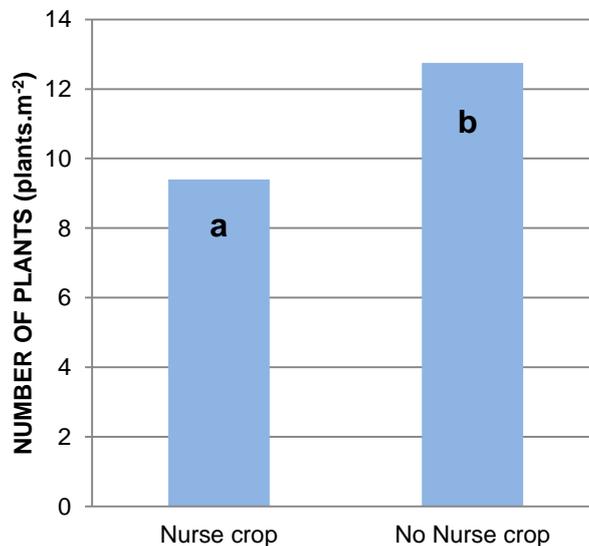


**Figure 3.9:** The number of *E. curvula* plants.m<sup>-2</sup> area (season one and –two) where nurse crop was a treatment.

# Means with the same letter are not significantly different at P>0.05

### *Digitaria eriantha* field experiment

#### Spring planting date - Season 1



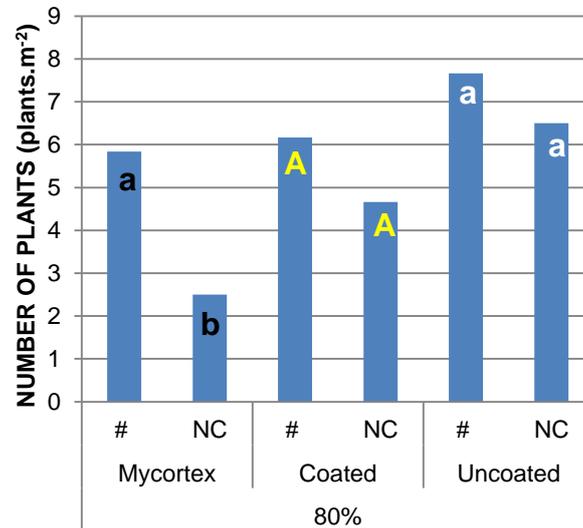
**Figure 3.10:** The number of *D. eriantha* plants.m<sup>-2</sup> area (season one, spring planting date) where nurse crop was a treatment.

# Means with the same letter are not significantly different at P>0.05

More *D. eriantha* plants were recorded where no nurse crop was planted (no inter-species competition) in season one of the spring planting date (Figure 3.10).

### Spring planting date - Season 2

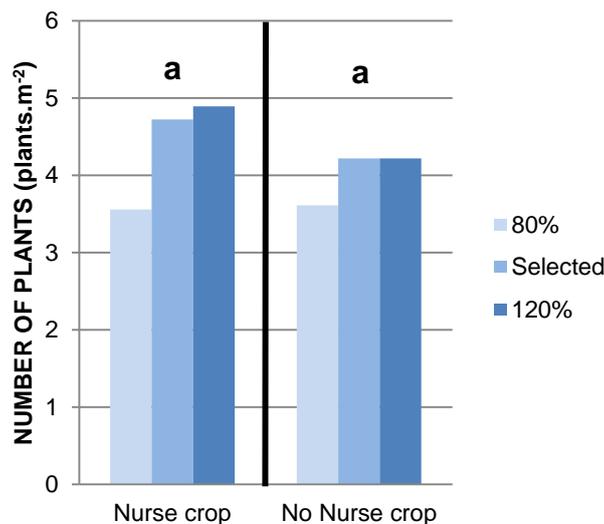
In season two of the same experiment, a similar trend ( $P>0.1$ ) was observed for Mycortex coated seed planted at the 80% seeding rate (weight basis) (Figure 3.11), indicating that more seed is required when nurse crop competition is evident.



**Figure 3.11:** The number of *D. eriantha* plants.m<sup>-2</sup> area (season two, spring planting date) as influence by the interactive effect of nurse crop- and seed coating treatments at 80% seeding rate (weight basis). # - No nurse crop, **NC** – Nurse crop.

# Means with the same letter are not significantly different at  $P>0.1$

### Autumn planting date



**Figure 3.12:** The number of *D. eriantha* plants.m<sup>-2</sup> area (season two, autumn planting date) where nurse crop was a treatment.

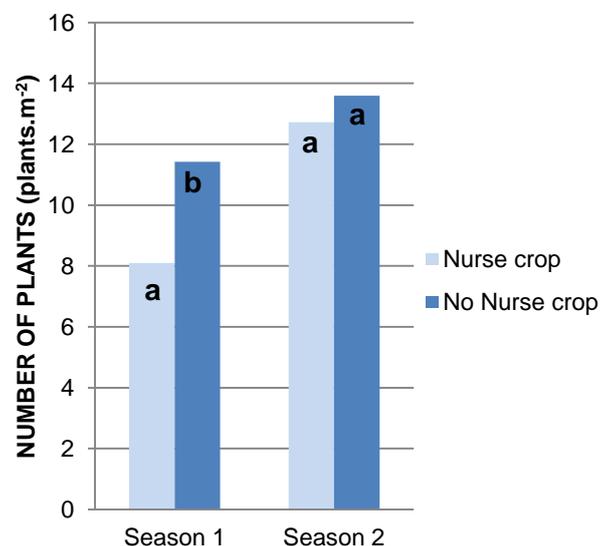
# Means with the same letter are not significantly different at  $P>0.05$

Plants in the autumn planting date experiment were only counted in season two. There were no significant differences seen between nurse crop treatments (Figure 3.12).

### ***Chloris gayana* field experiment**

#### **Spring planting date - Season 1 & 2**

A significant higher number of *C. gayana* plants were counted in season one compared to season two, where there were no significant differences (Figure 3.13). This increase in population in season two was due to the creeping characteristics of *C. gayana*.

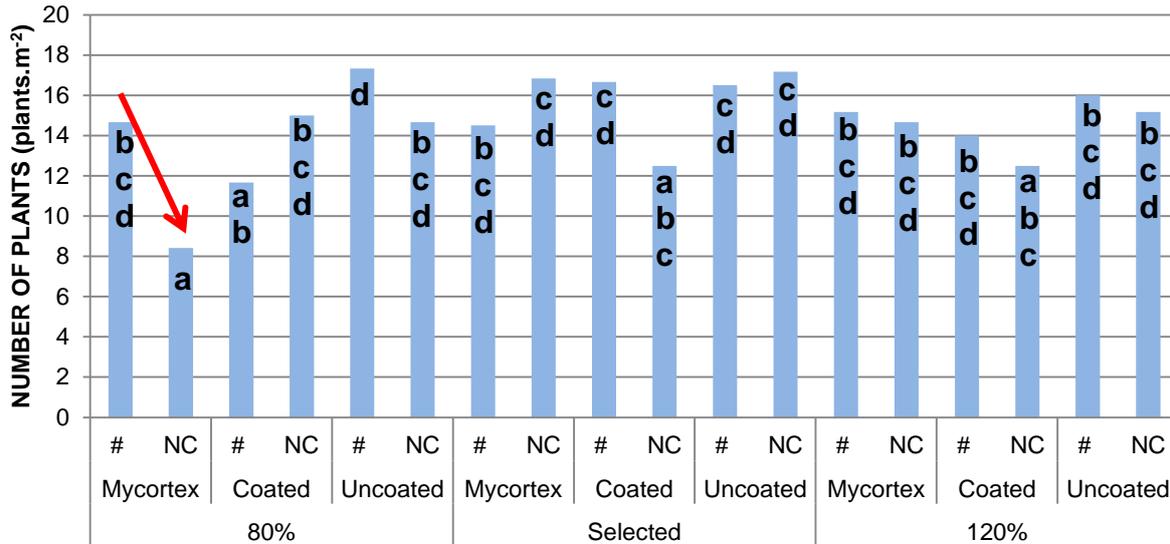


**Figure 3.13:** The number of *C. gayana* plants.m<sup>-2</sup> area (season one and –two, spring planting date) where nurse crop was a treatment.

# Means with the same letter are not significantly different at P>0.05

#### **Autumn planting date**

Plants in the autumn planting date experiment were only counted in season two. An interactive effect was seen where Mycortex seed, planted at 80% seeding rate (weight basis), had a significantly higher number of plants where no nurse crop was planted (Figure 3.14). This was due to the fact that Mycortex coated seed at 80% seeding rate (weight basis) contained less seeds.



**Figure 3.14:** The number of *C. gayana* plants.m<sup>-2</sup> area (season two, autumn planting date) as influenced by nurse crop-, seed coating- and seeding rate (weight basis) treatments. # - No nurse crop, **NC** – Nurse crop. The red arrow indicates the only nurse crop difference.

# Means with the same letter are not significantly different at P>0.1

## Conclusions

From the experiments conducted, meaningful results have been obtained. It can be concluded that planting at the 120% seeding rate for *E. curvula*, *D. eriantha* or *C. gayana* resulted in a higher plant density in the first season. An increased seeding rate of *E. curvula* or *C. gayana* did not have a significant effect on the number of plants in season two and intra-species competition and/or growth form characteristics resulted in the optimum plant densities being reached. The same trend was observed in season two data of *D. eriantha* at an autumn planting date. However, the spring planting date showed interactive effects. For *D. eriantha*, the number of plants in the second season was significantly higher when uncoated seed-120% seeding rate (weight basis) was planted without a nurse crop and significantly lower when Mycortex coated seed-80% seeding rate (weight basis) was planted with a nurse crop. When these two treatments were applied, the highest and lowest numbers of seed was planted, respectively. For uncoated seed at the 120% seeding rate, some seed planted in season one, only germinated in season two. There was subsequently no inter-species competition from the nurse crop in season one. The

season two data of the autumn planting date of *C. gayana* confirmed the poor establishment seen for the Mycortex coated-80% seeding rate in the *D. eriantha* spring experiment. This was due to the low number of seed being planted, with added competition from the nurse crop in season one. The fact that the conventional coating at 80% seeding rate did not show the same results, can also be indicative of the Mycortex coating substance being unfavourable to establishment.

Planting the *E. tef* nurse crop with *E. curvula* resulted in lower numbers of the perennial plants in the second season, than where weeds were controlled. This was due to inter-species competition, especially when it is taken into consideration that *E. tef* and *E. curvula* are species from the same genus (*Eragrostis*) and have many similar growth mechanisms and characteristics that make them fierce competitors. Planting the *E. tef* nurse crop with *D. eriantha* or *C. gayana* resulted in significantly lower perennial plants in season one, but no significant differences were observed between the numbers of plants in the second season, even in comparison with where weeds were controlled. The exception was where *D. eriantha* or *C. gayana* Mycortex coated seed was planted at the 80% seeding rate. Inter-species competition between *E. tef* and *D. eriantha* and *C. gayana* still occurred, but these species belong to different genus's, which makes them less aggressive in competing for resources.

The significant results from this study support the original hypotheses that adjusting the seeding rates and the use of a nurse crop does have significant effects on the establishment success of perennial species.

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## CHAPTER 4

Prepared according to the guidelines of African Journal of Range and Forage Science

### The role of seedbed preparation and seed conditioning techniques on sub-tropical grass species establishment

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#### Abstract

The execution of correct seedbed preparation and use of seed conditioning techniques such as seed coating are essential factors determining the success of planted pastures. *Eragrostis curvula*, *Digitaria eriantha* and *Chloris gayana*, the selected test species in this study, are commonly cultivated subtropical grass species in South Africa. Replicated field experiments were conducted in a Randomized Block Design, evaluating the pasture establishment success for coated seed [conventionally coated (three test species) and Mycortex coated (*D. eriantha* and *C. gayana*)] and uncoated seed in the context of variable seeding rate treatments (80% of selected seeding rate, selected seeding rate and 120% selected seeding rate) and in response to the use of an annual nurse crop (*Eragrostis tef*). The experiment included the measurement of establishment success of *E. curvula* where seedbed preparation techniques, rotavating and rolling (pre- and post-planting, respectively) were applied. It was concluded that all species had significantly higher pasture density in season one where uncoated seed was used due to a higher number of seeds planted. In season two, however, *E. curvula* and *C. gayana* plant densities showed no significant differences between the seed conditioning treatments. Seedbed preparations were found to be unsuccessful for *E. curvula*. The results obtained from these experiments showed the effects of seedbed preparation and seed conditioning techniques as a function of selected species.

**Keywords:** Coated seed, seedbed preparations, *Eragrostis curvula*, *Digitaria eriantha*, *Chloris gayana*.

## Introduction

Planting of pastures (replacing veld) in addition to reinforcing veld, improves the grazing capacity by increasing the Dry Matter (DM) production per hectare. It can furthermore have an enhancing effect on the nutritive value and digestibility and subsequent palatability of the DM produced (Aucamp 2000).

Various perennial, subtropical grass species are commercially available in South Africa. Tropical and subtropical grass species grow actively during summer but will become dormant during winter (Dannhauser 1991). During the growing season, most of these grasses can be grazed. The three subtropical grass species planted in this experiment, are commonly cultivated in South Africa and include *Chloris gayana* (var. Katambora), *Eragrostis curvula* (var. Ermelo) and *Digitaria eriantha* (var. Irene) (Dannhauser 1991, Van Oudtshoorn 1999).

Special care should be taken when establishing perennial pastures for use as forage in livestock production systems. Perennial grasses used for pastures are more vulnerable, since they have small seeds and are slow to establish. These species have delicate seedlings, compared to other crops and weeds and therefore, perennial pastures require more attention during establishment (Dannhauser 1991, McDonald and Keys 2002). If the establishment of pastures is poor, it will take expensive and highly intensive management to improve its performance. It is therefore clear why McDonald and Keys (2002) made the statement that “the most expensive pasture is the one that fails to establish properly”.

The following four abiotic factors can have an influence on seed germination and seedling establishment in the soil environment; (i) water, (ii) oxygen, (iii) temperature and (iv) mechanical impedance (Hadas 2004). These requirements of grass pastures can be met by planting in soil with good chemical and physical properties (Dannhauser and De Beer 1987, Dannhauser 1991, Bartholomew 2000).

The techniques used to improve the success with which pastures are established include the conditioning or coating of seed (Copeland and McDonald 2001, Heritage Seeds 2011), controlling seedbed quality (Douglast Koppi 1997, Atkinson et al. 2009), seedbed consolidation (Dannhauser 1991, Couture et al. 2004), altering the seeding rate (Lemus 2008, Bartholomew 2000) and planting of nurse crops (Dannhauser 1991, Bartholomew 2000).

Pre-establishment technique such as seed coating is a possible method to overcome the vulnerability of the perennial pasture during establishment as a result of small seed and unknown seedling vigour (Heritage Seeds 2011). Seed coating is a process of applying layers of substances such as pesticides, growth stimulators, dormancy-breaking substances, limestone, micronutrients and even macronutrients without drastically changing the shape of the seed (Copeland and McDonald 2001, Heritage Seeds 2011). In addition to the abiotic factors affecting establishment; biotic factors such as endo-mycorrhizas can also determine the success with which seedlings establish and grow. Endo-mycorrhizas are fungi that can form symbiotic associations with most plants. Arbuscules grow into the host plant's root cells through which nutrient exchange can take place between the plant and fungi (Miyasaka et al. 2003). Seeds can be coated with a Mycortex S coating to facilitate symbiotic nutrient exchange and prevent fungal infections (Biotechnica 2011).

Three characteristics that are needed for a good seedbed are: (i) fineness and firmness (to ensure good seed-soil contact), (ii) evenness and smoothness (for precise placement of seeds at the right depth) and (iii) a weed-free area as far as possible (to avoid competition with aggressive weed seedlings) (Dannhauser 1991, Macdonald 2005). In preparing a good seedbed, a rotavator can be used, which is a tillage implement that is capable of producing the desired soil tilth quality with fewer tillage actions, rather than using other methods like harrowing (Marenya 2009). Alternatively tiller implements can be used repeatedly to ensure a fine, smooth and even seedbed (Douglast Koppi 1997, Atkinson et al. 2009). Possibly the most important practice in forage crop production is to roll or consolidate (lightly compact) the well prepared seedbed before and/or after planting to improve seed-soil contact and improve seedbed firmness (Dannhauser 1991, Couture et al. 2004).

According to Bartholomew (2000) the seeding rate can be adapted because of the following reasons: (i) purity, (ii) germination percentage, (iii) seed size, (iv) seed weight, (v) soil fertility and soil moisture, (vi) seedbed quality, (vii) sowing method, (viii) pasture purpose and (ix) perenniality of pasture.

When a farmer wants to establish a perennial species, but has an immediate need of forage, an annual species like *Eragrostis tef* can be planted as a nurse crop with the perennial species to ensure available forage in the first season (Dannhauser 1991, Bartholomew 2000).

Broadcast seeding pastures is a common practice used to establish pastures. This method is, however, more successful in high rainfall areas (Dannhauser 1991). For optimal subtropical grass pasture production, soil pH (KCl) > 5 - [pH (H<sub>2</sub>O) > 6], soil phosphorous (P) levels must be at least 20 mg.kg<sup>-1</sup> and potassium (K) levels at least 130 mg.kg<sup>-1</sup> (Pasture Handbook 2007, FSSA 2013).

The aim of this study was to determine whether (i) controlling seedbed quality and/or (ii) using seed conditioning techniques such as seed coating has any significant effect on the establishment success of the test grass species. It is therefore hypothesized that controlling the seedbed quality and the use of seed coating will have significant effects on the establishment success of the perennial species.

## **Materials & Methods**

### ***Study site***

An experimental site was selected at the field experiment section of the University of Pretoria's Experimental farm in Hatfield, Pretoria. The three experiments in this study were conducted under dry land conditions, with supplementary irrigation when it was required to prevent stand failure. Environmental factors such as temperature, moisture, wind and soil variance was not controlled. Representative soil samples were taken from the experimental site and analysed at the University of Pretoria's Department of Plant Production and Soil Science's laboratory. The soil (Hutton – sandy clay loam) used in this study had a clay percentage of 24.0%, pH - 6.1 (H<sub>2</sub>O), phosphorous (P) – 27.5 mg.kg<sup>-1</sup>, potassium (K) – 28.0 mg.kg<sup>-1</sup>, calcium (Ca) – 363.0 mg.kg<sup>-1</sup>, magnesium (Mg) – 93.0 mg.kg<sup>-1</sup>, soil carbon (C) – 0.7 %. The experimental design was a RCBD.

### ***General experimental procedures***

*The following experimental procedures were applied to all experiments:*

Three experiments were performed in the field using *C. gayana* (var. Katambora), *E. curvula* (var. Ermelo) and *D. eriantha* (var. Irene). Fertilization was conducted according to the soil analysis. During seedbed preparation, all existing plant material was removed from the experimental site and the surrounding areas.

Thereafter the soil was deeply ripped, using a three tine ripper. Phosphorous was applied using super phosphate (Super P) according to the soil analysis to acquire a soil P level of  $30 \text{ mg.kg}^{-1}$  ( $8 \text{ kg P.ha}^{-1}$  was required). This was followed by discing the soil, then ploughing and by discing again. Hereafter seedbed preparations were very treatment specific and the treatments were allocated accordingly. Nitrogen and potassium was applied at planting:

- i) Nitrogen in the form of limestone ammonium nitrate (LAN) –  $50 \text{ kg N.ha}^{-1}$ .
- ii) Potassium in the form of potassium chloride (KCl) to acquire a level of  $120 \text{ mg.kg}^{-1}$  ( $343 \text{ kg K.ha}^{-1}$  was required).



**Figure 4.1:** Fertilizer, in the form of LAN and KCl, being applied to allocated plots.

After the fertilizer was lightly worked into the top 100 mm of the soil, the seed was broadcasted according to the specified seeding rate treatments and nurse crop treatment allocations. After planting, consolidation of plots was done. The soil was irrigated with 25 mm of water immediately after planting using a sprinkler system. Experiments were harvested three times in season one and four times in season two

determined by 10% flowering stage. For autumn planting dates, only one harvest was obtained in season one at 10% flowering stage. After each harvest 75 kg N.ha<sup>-1</sup> was applied as top-dress fertilizer.

The type of seed coating used and the species being coated both had effects on the number of seeds being planted per kg seed. The ratios of uncoated seed to coated seed for each species are given in Table 4.1.

**Table 4.1:** Ratios of seed numbers between uncoated, coated and Mycortex coated seed for the same mass of seed.

Species	Uncoated	Coated	Mycortex Coated
<i>E. curvula</i>	1	0.45	-
<i>D. eriantha</i>	1	0.21	0.20
<i>C. gayana</i>	1	0.13	0.11

The seeding rates were selected for test species as this is the current commercial recommendation (Pasture Handbook 2007). The adapted seeding rates were 20% lower- and 20 % higher (Table 4.2), than the recommend rate.

**Table 4.2:** Seeding rates (kg.ha<sup>-1</sup>) used for every species.

Species	80%	Selected	120%
<i>E. curvula</i>	5.6	7	8.4
<i>D. eriantha</i>	6.4	8	9.6
<i>C. gayana</i>	5.6	7	8.4

### ***Eragrostis curvula* field experiment**

A total number of 144 plots (3m x 3m) were planted in this experiment. Each treatment was replicated three times. The experimental design is summarized in Table 4.3. Treatments included:

- i. **Rotavated and non-rotavated seedbed:** To get an even, fine and firm seedbed the whole experiment area was tilled with a clot breaking roller behind it

that ensures a level seedbed without big clots. After the seedbed was prepared, the applicable plots were rotavated (Figure 4.2 and 4.3).



**Figure 4.2:** Seedbed preparation using a rotavator.



**Figure 4.3:** A fine seedbed prepared with a rotavator (left of the black line) compared to seedbed prepared with a conventional tilling implement (right).

ii. **Coated and uncoated seed:** Coated and uncoated seed from the same seed batch was provided by a reputable and registered seed company.

iii. **Three seeding rates used:** For the 80% seeding rate, selected seeding rate, and 120% seeding rate the coated- and uncoated seed weight was the same. The coating substance, however, substituted seed in the case of coated seed on the basis of weight. *Eragrostis curvula* uncoated seed was 2.2 times more in

numbers than the coated seed, while the same weight of seed was planted (Table 4.1).

iv. **Nurse crop:** *Eragrostis tef* was planted at a fixed recommended seeding rate of 5 kg.ha<sup>-1</sup> to serve as a nurse crop. This is the lowest rate recommended by Dannhauser (1991). Control plots were planted without a nurse crop.

v. **Rolled and non-rolled seedbed:** After planting, some plots were rolled using a Cambridge roller, while other plots were not rolled.



**Figure 4.4:** Seedbed consolidation after planting using a Cambridge roller.



**Figure 4.5:** A firm consolidated seedbed (left of the black line) compared to an unconsolidated seedbed (right).

**Table 4.3:** *Eragrostis curvula* experimental treatments (Summary).

Treatment	Factor by which the experimental units increase	Description
Rotavated	2	<ul style="list-style-type: none"> <li>Rotavated vs. non-rotavated prior to planting</li> </ul>
Coated	2	<ul style="list-style-type: none"> <li><i>E. curvula</i> was coated or uncoated</li> </ul>
Nurse crop	2	<ul style="list-style-type: none"> <li><i>E. tef</i> used or not used as nurse crop</li> </ul>
Seeding rates	3	<ul style="list-style-type: none"> <li>80%, 100% and 120% of a selected seeding rate</li> </ul>
Rolling	2	<ul style="list-style-type: none"> <li>Rolled vs. non-rolled after planting</li> </ul>
Replications	3	

### ***Experimental procedure***

No rain was recorded at the experimental site for the first two weeks after planting. The experiment was irrigated with 75 mm of water during this period distributed as five applications of 15 mm. The experiment was harvested three times during the first season and four times during the second season as determined by the 10% flowering stage. One month after planting, Basagran® (active ingredient, Bentazone) a herbicide against nutsedge and broadleaf weeds, was applied. At the start of the second season Basagran® was applied again. At the end of the first season the number of *Eragrostis* (*E. curvula* and *E. tef*) plants was counted in two, one m<sup>2</sup> quadrates in each plot. At the end of the second season the number of *E. curvula* plants was again counted using the same technique.

Data were analysed, using the statistical program GenStat® (Payne et al. 2012). A split-split plot RCBD was established where the whole plots were rolled or not rolled, the sub-plots were rotavated or not rotavated. The two seed coating treatments x two nurse crop x three seeding rates = 12 factorial treatments were the sub-sub-plots assigned randomly to the sub-plots. The design was replicated three times. Analysis of variance was applied to test for significant effects of all the main

effects and their interactions. The distribution and variances were tested and found to be acceptably normal and homogeneous (Bartlett's test). Treatment means were separated using Fisher's least significant difference (LSD) test at the 5% level of significance (Snedecor & Cochran 1980).

### ***Digitaria eriantha* field experiment**

A total number of 108 plots (3m x 4m) were planted in this experiment. Each treatment was replicated three times. The experimental design is summarized in Table 4.4. To get an even, fine and firm seedbed the whole experiment was rotavated after the initial seedbed preparation and rolled after planting. Treatments included:

i. **Coated, Mycortex (product name - Mycortex S) coated and uncoated seed:** Treated and untreated seeds from the same batch of seed were provided by a reputable and registered seed company. Treated seed were coated with a conventional seed coating and Mycortex coating. Mycortex coated seed contained the same substances as the conventional coating, with the added Mycortex ingredient.

ii. **Three seeding rates:** For the 80% seeding rate, selected seeding rate, and 120% seeding rate the coated- and uncoated seed weight was the same (Table 4.2). The coating substance will, however, substitute seed in the case of coated seed on the basis of weight. *Digitaria eriantha* seed number ratios are indicated in Table 4.1.

iii. **Nurse crop:** *Eragrostis tef* was planted at a fixed recommended seeding rate (5 kg.ha<sup>-1</sup>) to serve as a nurse crop. This seeding rate was the lowest rate recommended by Dannhauser (1991). Some plots were planted without a nurse crop.

iv. **Two planting dates:** The experiment was planted in spring and repeated in the following autumn. There was, however, no comparison made between the two planting dates, because of variable environmental factors.

**Table 4.4:** *Digitaria eriantha* experimental treatments (Summary).

Treatment	Factor by which the experimental units increase	Description
Coated	3	<ul style="list-style-type: none"> <li><i>D. eriantha</i> was coated, Mycortex coated or uncoated</li> </ul>
Nurse crop	2	<ul style="list-style-type: none"> <li><i>E. tef</i> used or not used as nurse crop</li> </ul>
Seeding rates	3	<ul style="list-style-type: none"> <li>80%, 100% and 120% of a selected seeding rate</li> </ul>
Two planting dates	2	<ul style="list-style-type: none"> <li>Spring and autumn</li> </ul>
Replications	3	

### ***Experimental procedures***

*Spring planting date:* There was no rain recorded on the spring planting date site for the first week after planting. The experiment was irrigated with approximately 45 mm of water as three applications of 15 mm each. One month and three months after planting, Basagran® (active ingredient, Bentazone) a herbicide against nutsedge and broadleaf weeds, was applied. At the start of the second season Basagran® was applied again. At the end of the first season the number of established *D. eriantha*, and *E. tef* plants were counted in two, one m<sup>2</sup> quadrates in each plot for the spring planting date. The spring planting date experiment was evaluated again in the same way after the second season.

*Autumn planting date:* The same process of seedbed preparation and planting was used. Glyphosate was applied twice in the summer to keep the site weed free. For the autumn planting date 25 mm was irrigated after planting, Basagran® was applied once, one month after planting. For the autumn planting date the same plant count was done at the end of the second season. There was no evaluation in the season of planting. To quantify plant numbers, the pasture had to be harvested in order to get a clear view of all plants. It was decided not to harvest newly established plants (seedlings) prior to winter.

Data were analysed using the statistical program GenStat® (Payne et al. 2012). The layout was a RCBD arranged as a three x two x three factorial experiment. Treatments included three coated seed, two nurse crop, three seeding rates, amounting to 18 treatments. The design was replicated three times for each of two planting dates. Analysis of variance was applied to test for significant effects of all the main effects and their interactions. The errors and variances were tested and found to be acceptably normal and homogeneous (Bartlett's test). Treatment means were separated using Fisher's least significant difference (LSD) test at the 5% level of significance (Snedecor & Cochran 1980).

### ***Chloris gayana* field experiment**

A total number of 108 plots (3m x 4m) were planted in this experiment. Each treatment was replicated three times. The experimental design is summarized in Table 4.5. To get an even, fine and firm seedbed the whole experiment was rotavated after the initial seedbed preparation and rolled after planting. Treatments included:

**i. Coated, Mycortex S (product name - Mycortex S) coated and uncoated seed:** Treated and untreated seeds from the same batch of seed were provided by a reputable and registered seed company. Treated seed were coated with a conventional seed coating and Mycortex coating. Mycortex coated seed contained the same substances as the conventional coating, with the added Mycortex ingredient.

**ii. Seeding rates:** For the 80% seeding rate, selected seeding rate, and 120% seeding rate the coated- and uncoated seed weight was the same (Table 4.2). The coating substance will, however, substitute seed in the case of coated seed on the basis of weight. *Chloris gayana* seed number ratios are indicated in Table 4.1.

**iii. Nurse crop:** *Eragrostis tef* was planted at a fixed recommended seeding rate (5 kg.ha<sup>-1</sup>) to serve as a nurse crop. This seeding rate is the lowest rate recommended by Dannhauser (1991). Control plots were planted without a nurse crop.

**iv. Two planting dates:** The experiment was planted in spring and repeated in the following autumn. There will however be no comparison between the two planting dates, because of variable environmental factors.

**Table 4.5:** *Chloris gayana* experimental treatments (Summary).

Treatment	Factor by which the experimental units increase	Description
Coated	3	<ul style="list-style-type: none"> <li><i>C. gayana</i> was coated, Mycortex coated or uncoated</li> </ul>
Nurse crop	2	<ul style="list-style-type: none"> <li><i>E. tef</i> used or not used as nurse crop</li> </ul>
Seeding rates	3	<ul style="list-style-type: none"> <li>80%, 100% and 120% of a selected seeding rate</li> </ul>
Two planting dates	2	<ul style="list-style-type: none"> <li>Spring and autumn</li> </ul>
Replications	3	

### ***Experimental procedures***

*Spring planting date:* There was no rain recorded on the spring planting date site for the first week after planting. The experiment was irrigated with approximately 45 mm of water as three applications of 15mm each. One month and three months after planting, Basagran® (active ingredient, Bentazone) a herbicide against nutsedge and broadleaf weeds, was applied. At the start of the second season Basagran® was applied again. At the end of the first season the number of established *C. gayana*, and *E. tef* plants were counted in two, one m<sup>2</sup> quadrates in each block for the spring planting date. The spring planting experiment was evaluated again in the same way after the second season.

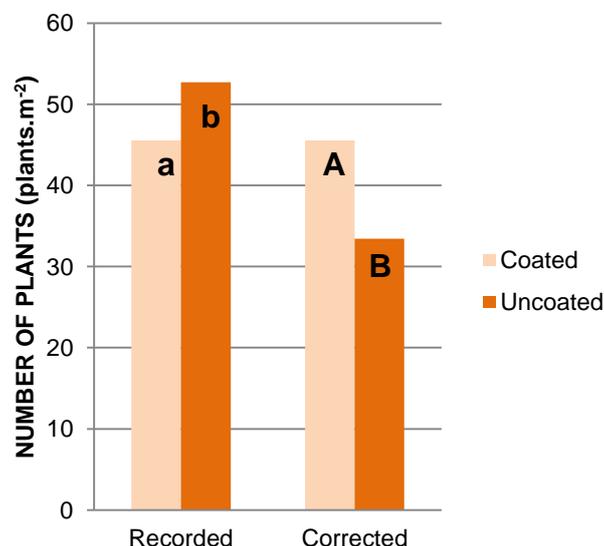
*Autumn planting date:* The same process of preparation and planting was implemented. Glyphosate was applied twice in the summer to keep the site weed free. For the autumn planting date 25 mm was irrigated after planting and Basagran® was applied once one month after planting. For the autumn planting date the same plant count was done but only at the end of the second season. There was no evaluation in the season of planting. To quantify plants, the pasture had to be harvested first in order to get a clear view of all plants. It was decided not to harvest newly established plants (seedlings) prior to winter.

Data were analysed using the statistical program GenStat® (Payne et al. 2012). The layout was a RCBD arranged as a three x two x three factorial experiment. Treatments included three coated seed, two nurse crop, three seeding rates, amounting to 18 treatments. The treatments were replicated three times for each of two planting dates. Analysis of variance was applied to test for significant effects of all the main effects and their interactions. The errors and variances were tested and found to be acceptably normal and homogeneous (Bartlett's test). Treatment means were separated using Fisher's least significant difference (LSD) test at the 5% level of significance (Snedecor & Cochran 1980).

## Results and Discussion

### *Eragrostis curvula* field experiment

In season one all the plants of *E. curvula* and *E. tef* species were counted, since it was difficult to distinguish between them as young plants. There was a significantly higher number of *Eragrostis* plants counted for uncoated seed (Figure 4.6). This is attributed to a higher number of seed sown and first-season-plants still being small and uncompetitive. However, this scenario changed when the count was corrected.

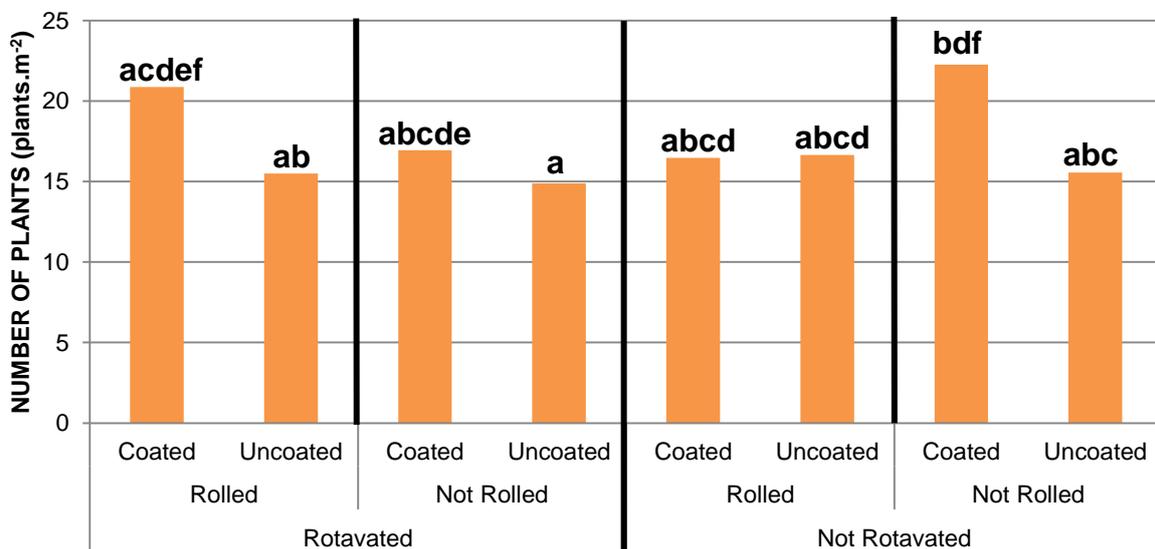


**Figure 4.6:** Recorded and corrected data showing the number of *Eragrostis* plants.m<sup>-2</sup> area (season one), where coated and uncoated seed was planted.

# Means with the same letter are not significantly different at P>0.05

It was easier to distinguish between *E. curvula* and the few new *E. tef* plants in season two and therefore, only *E. curvula* plants were counted. No significant differences were observed in season two (Figure 4.7). *Eragrostis curvula* plants became less as competition increased at the end of the first season and tufts grew larger.

The success of seedbed preparation techniques (rotavating the seedbed prior to- and rolling the seedbed after planting) was not significant in season two (Figure 4.7). In the first season of evaluation, the data also showed no significance in rolling/rotavating the seedbed. Due to the fact that 75 mm of irrigation was applied after planting, the effect of having a fine, firm seedbed was not beneficial, since there was no moisture stress.



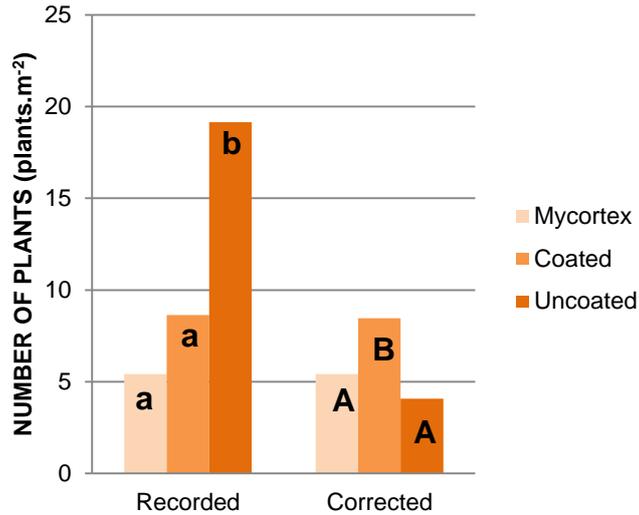
**Figure 4.7:** The number of *Eragrostis curvula* plants recorded in m<sup>-2</sup> area (season two) as influenced by the interactive effect of seed coating-, rotavating- and rolling treatments.

# Means with the same letter are not significantly different at P>0.05

### ***Digitaria eriantha* field experiment**

#### **Spring planting date - Season 1**

It was noted in this experiment that the *D. eriantha* count of uncoated seed showed the best recorded establishment and can possibly be attributed to a higher number of seed sown and first-season-plants still being small and uncompetitive (Figure 4.8). When the number of plants was corrected for the number of seeds planted, the coated seed showed the best establishment success rate.

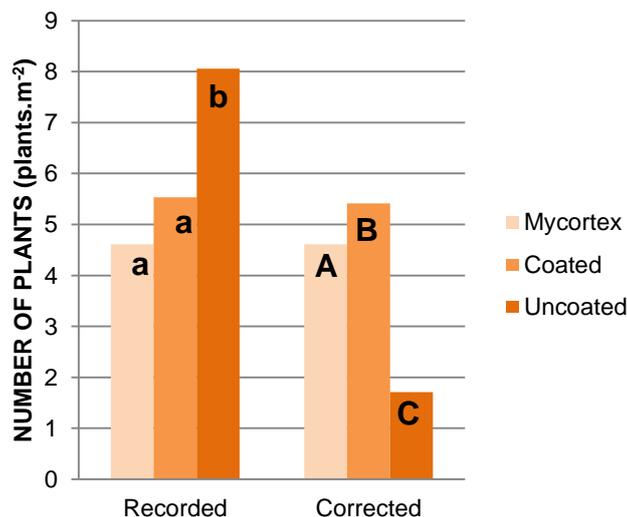


**Figure 4.8:** Recorded and corrected data showing the number of *D. eriantha* plants.m<sup>-2</sup> area (season one, spring planting date), where coated, Mycortex coated and uncoated seed was planted.

# Means with the same letter are not significantly different at P>0.05

### Spring planting date - Season 2

In season two the recorded count of uncoated seed still showed the best establishment (Figure 4.9). However, plants corrected for the number of coated seeds planted, showed a better establishment success rate.

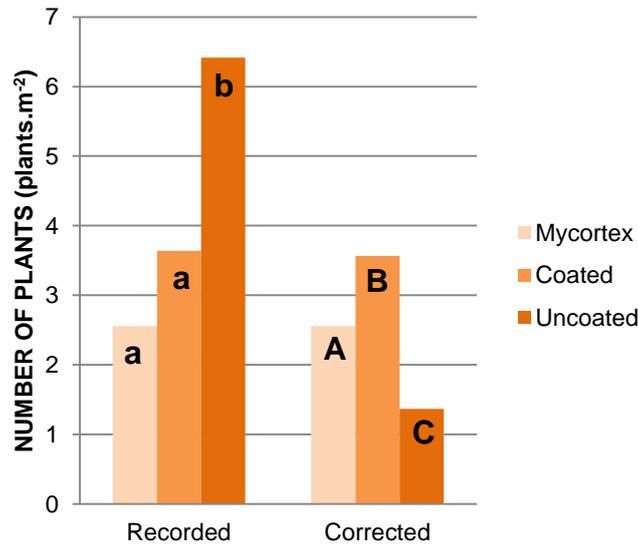


**Figure 4.9:** Recorded and corrected data showing the number of *D. eriantha* plants.m<sup>-2</sup> area (season one, spring planting date), where coated, Mycortex coated and uncoated seed was planted.

# Means with the same letter are not significantly different at P>0.05

### Autumn planting date

Plants in the autumn planting date experiment were only counted after season two. In this experiment the recorded count of uncoated seed showed the best establishment (Figure 4.10). However, the number of plants corrected for the number of coated seeds planted, showed a better establishment success rate.



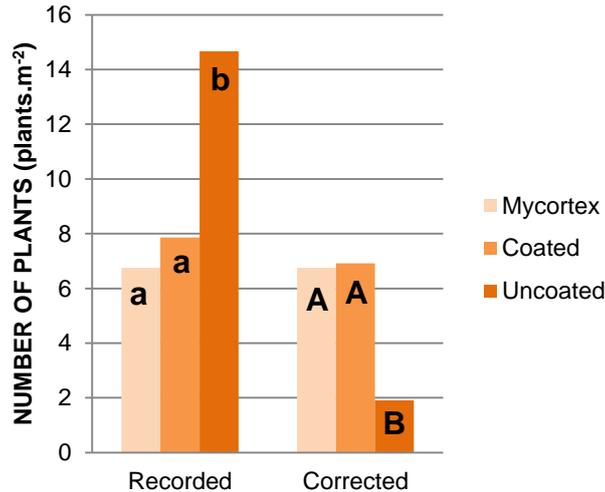
**Figure 4.10:** Recorded and corrected data showing the number of *D. eriantha* plants.m<sup>-2</sup> area (season two, autumn planting date), where coated, Mycortex coated and uncoated seed was planted.

# Means with the same letter are not significantly different at P>0.05

### *Chloris gayana* field experiment

#### Spring planting date - Season 1

For *C. gayana* the recorded count of uncoated seed showed the best establishment (Figure 4.11). This is attributed to a higher number of seed sown and first-season-plants still being small and uncompetitive. When the number of plants is corrected for the number of seeds planted, both the coated treatments showed a better establishment success rate.

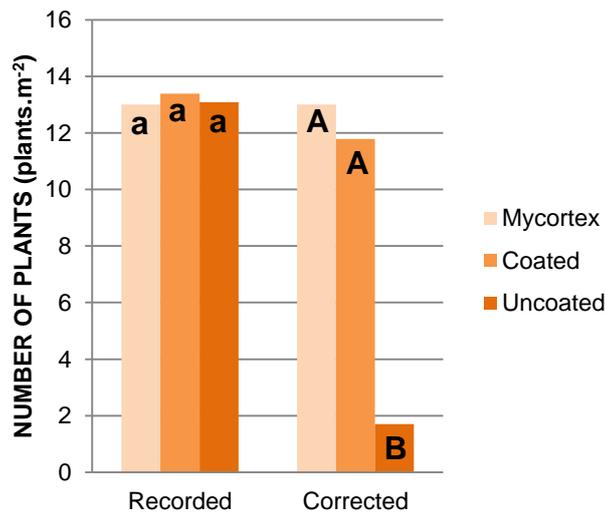


**Figure 4.11:** Recorded and corrected data showing the number of *C. gayana* plants.m<sup>-2</sup> area (season one, spring planting date), where coated, Mycortex coated and uncoated seed was planted.

# Means with the same letter are not significantly different at P>0.05

### Spring planting date - Season 2

In season two the *C. gayana* recorded count showed no significant difference (Figure 4.12). This is attributed to the creeping growth form characteristics of *C. gayana*. When the number of plants is corrected for the number of seeds planted, both the coated treatments showed a better establishment success rate.

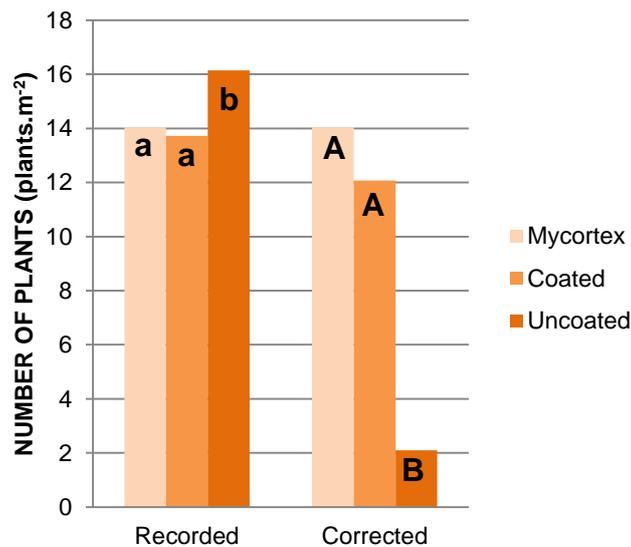


**Figure 4.12:** Recorded and corrected data showing the number of *C. gayana* plants.m<sup>-2</sup> area (season one, spring planting date), where coated, Mycortex coated and uncoated seed was planted.

# Means with the same letter are not significantly different at P>0.05

### Autumn planting date

Plants in the autumn planting date experiment were only counted after season two. There was no evaluation in the season of planting. In this experiment the recorded count of uncoated seed showed the best establishment (Figure 4.13). However, when the number of plants is corrected for the number of seeds planted, both of the coated treatments showed better establishment success.



**Figure 4.13:** Recorded and corrected data showing the number of *C. gayana* plants.m<sup>-2</sup> area (season two, autumn planting date), where coated, Mycortex coated and uncoated seed was planted.

# Means with the same letter are not significantly different at P>0.05

## Conclusions

The field experiments conducted brought forth data from which it can be concluded that uncoated seed of *E. curvula*, *D. eriantha* and *C. gayana* had a significantly higher establishment success in the first season when planted at the same seeding rate (weight basis), compared to coated and Mycortex coated seed. The higher number of seed sown when using uncoated seed, resulted in a higher plant density in season one.

As time progressed, the uncoated seedlings of *E. curvula* thinned out and became less due to intra-species competition, resulting in an optimum plant density being reached in season two. There were no significant differences between coated

and uncoated *E. curvula* seed treatments observed in season two. This can be ascribed to *E. curvula* seeds being small enough and its shape allowing only a small amount of coating substance to be applied, compared to other species.

After two seasons, *D. eriantha* plants still had a higher plant density where uncoated seed was planted. This was due to more seed being planted and seed still germinating in season two. Because of seed shape, size and other morphological characteristics, *D. eriantha* absorbs large amounts of coating substance during the coating process and without having the creeping characteristics of *C. gayana*, the small numbers of coated *D. eriantha* seeds that was planted, led to a low plant density.

Plants from coated and Mycortex coated seed *C. gayana* increased in season two due to their creeping characteristics. After two seasons, no significant differences were observed between the plant densities of the seed coating treatments on *C. gayana*'s spring planting date experiment. The autumn planting date, however, showed a significantly higher number of plants for uncoated seed.

The establishment success rate (number of plants established per number of seeds planted) was calculated for all the data recorded in the three experiments mentioned in this chapter. Seed treated with a coating substance had a higher success rate than that of uncoated seed because less seed were planted. The establishment success rate of coated and Mycortex coated seed was therefore higher than where uncoated seed was used.

*Eragrostis curvula*, *D. eriantha* and *C. gayana* were irrigated well after planting up to establishment. Therefore the effect of rotavating and rolling the soil was not significant. Where no moisture stress was apparent, the effects of seedbed preparations were not evident.

The significant results from this study support the original hypothesis that conditioning of seed by using coating substances does have significant effects on the establishment success of the perennial species, mainly due to the number of seeds planted. Controlling the seedbed quality does not have significant effects where pastures are irrigated until establishment.

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## CHAPTER 5

### General conclusions and recommendations

#### ***The effect of pre-establishment techniques on the establishment and growth of three subtropical species in a controlled environment***

In favourable conditions, seed can hypothetically germinate within two to three days after planting. Pre-establishment techniques are also known as seed- and soil preparation techniques, applied in order to successfully establish pasture. According to literature, some of these techniques are particularly effective in unfavourable/unpredictable environments.

Seed coating showed no significant differences on the establishment or growth of test species (*Eragrostis curvula*, *Digitaria eriantha* and *Chloris gayana*) in a controlled environment. There was, however, a delayed germination and emergence of coated *E. curvula* seed in the controlled environment. This was attributed to the dissolving of the coating before germination could commence. It is assumed that the coating substance first had to be saturated before water reached the seed, causing a delay in imbibition and the subsequent stages of germination. Under controlled environmental conditions, fortunately, there was an abundance of water available for the seed coating to dissolve, causing only delayed germination and not a decline in germination.

Under controlled environmental conditions, growth space is often the only growth limiting factor. Adapting the seeding rate upwards or downwards (on a weight basis) in a controlled environment, with ideal germination and growing conditions, resulted in no significant differences between DM yields. This was as a result of no competition for nutrients and moisture. However, competition for space between less or more plants existed. The optimum plant density for every container was reached, irrespective of the seeding rates planted.

Where an annual nurse crop (*E. tef*) was planted with the perennial species (*E. curvula*), the annual germinated and established before the perennial and increased the

competition effect between species. The successful establishment of the nurse crop resulted in higher DM yields.

According to literature, consolidating the seedbed after planting will result in higher moisture availability to seed in the topsoil. In a controlled environment (with abundance in moisture availability) the true effect of consolidation of the seedbed was not seen. By using techniques to further prevent rapid drying of the topsoil, water could not drain effectively from soil that were consolidated and resulted in waterlogged conditions. This caused low germination and emergence from consolidated soil.

The insignificant results from this study support the original hypothesis that favourable growing conditions reduce the functions of pre-establishment techniques, during the facilitated establishment of sown pasture seed.

### ***Inter- and intra-species competition as influenced by variable seeding rates and nurse crop association***

By planting an annual nurse crop (*E. tef*) with a perennial species (*E. curvula*, *D. eriantha* and *C. gayana*), inter-species competition was created. By adjusting the seeding rate of the perennial species upwards or downwards, intra-species competition was increased or decreased respectively.

From the field experiments conducted, it was concluded that planting at the 120% seeding rate for *E. curvula*, *D. eriantha* or *C. gayana* resulted in a higher plant density in season one. This was due to more seed being planted and since seedlings were small and uncompetitive, there existed no intra-species competition in the first season. By the end of season two, tufts of established plants grew larger and intra-species competition increased. This resulted in *E. curvula* not having a significant difference in the number of plants at different seeding rate treatments in season two. *Chloris gayana* also showed no difference in the number of plants at the different seeding rate treatments at the end of season two, but this can be ascribed to the creeping (stoloniferous) growth characteristics of *C. gayana*. During the coating process, *D. eriantha* seed absorbs more than twice as much coating substance as *E. curvula* due to morphological differences. Furthermore, *D. eriantha* does not have the creeping characteristic of *C. gayana*. This is why the number of *D. eriantha* plants in

season two was still significantly lower where Mycortex coated seed-80% seeding rate (weight basis) was planted with a nurse crop (creating inter-species competition). When applying this treatment the lowest number of seeds was planted with competition from the nurse crop. *Chloris gayana* data confirmed the poor establishment seen for Mycortex coated-80% seeding rate. The fact that the conventional coating at the 80% seeding rate did not show the same results, can also be indicative of the Mycortex coating substance being unable to facilitate successful establishment. The second season's number of established *D. eriantha* plants was significantly higher when uncoated seed-120% seeding rate (weight basis) was planted without a nurse crop (no inter-species competition). For the uncoated seed-120% seeding rate, some seed planted in season one only germinated in season two because of the high number of seed planted. This ability of seed to still germinate long after being planted is a known characteristic of *D. eriantha*.

Creating inter-species competition by planting an annual nurse crop (*E. tef*) with *E. curvula*, resulted in lower numbers of the perennial plants in the second season. This was due to inter-species competition, especially when it is taken into consideration that *E. tef* and *E. curvula* are spp. from the same genus (*Eragrostis*). It is assumed that this makes them aggressive competitors at many levels, since they have many similar growth mechanisms and characteristics. Creating inter-species competition by planting *E. tef* as a nurse crop with *D. eriantha* or *C. gayana* resulted in significantly lower perennial plants in season one, but no significant differences were observed in season two. The exception was where *D. eriantha* or *C. gayana* Mycortex coated seed was planted at the 80% seeding rate. Even though inter-species competition between *E. tef* and *D. eriantha* and *C. gayana* occurred, they belong to different genus's which made them less aggressive in competing for resources.

The significant results from this study support the original hypothesis that adjusting the seeding rates and the use of a nurse crop does have significant effects on the establishment success of the perennial species.

## ***The role of seedbed preparation and seed conditioning techniques on sub-tropical grass species establishment***

Controlling seedbed quality by ensuring good seedbed preparation and consolidating the seedbed after planting are techniques that are usually effective in unfavourable/unpredictable environments. By applying these techniques, planting depth and seed-soil contact can be controlled, allowing effective moisture uptake and successful establishment. By irrigating *E. curvula*, *D. eriantha* and *C. gayana* from planting until establishment resulted in the effect of rotavating and rolling the soil being insignificant.

Seed conditioning techniques, like the coating of seed, physically add ingredients to the seed. The coating substance is an obstruction for seed moisture uptake. The coating substance also substitutes seed when seeding rates per hectare are recommended on a weight basis. Seed coating does, however, improve the handling of seed and the ease with which it can be planted and ensures precise placement. Uncoated seed of *E. curvula*, *D. eriantha* and *C. gayana* had a significantly higher establishment success in the first season when planted at the same seeding rate (weight basis) as conventionally coated and Mycortex coated seed. This was due to a higher number of seed sown when using uncoated seed.

Uncoated seedlings of *E. curvula* became less due to intra-species competition as tufts grew larger in season two, resulting in an optimum plant density being reached by the end of season two. No significant differences were observed between coated and uncoated *E. curvula* seed treatments in season two. Due to the size and shape of *E. curvula* seeds only a small amount of coating substance is applied during the coating process. This creates less of an obstruction, resulting in more seed on a weight basis, compared to other species.

*Digitaria eriantha* plants still had a higher plant density after season two where uncoated seed was planted. By using uncoated seed, much more seed was planted, of which some were still germinating in season two. Because of seed shape, size and other morphological characteristics, *D. eriantha* absorbs large amounts of coating substance during the coating process and without having the creeping characteristics of

*C. gayana*, *D. eriantha* couldn't overcome the low plant density caused by the little number of seed planted when using coated seed.

The number of plants from *C. gayana* seed treated with any coating increased in season two, due to its creeping characteristics. No significant differences were observed between the plant densities of the seed coating treatments after two full seasons.

The significant results from this study support the original hypothesis that conditioning of seed by using coating substances does have significant effects on the establishment success of the perennial species. Controlling the seedbed quality does not have significant effects where pastures are irrigated until establishment.

### **Recommendations**

Seeding rates can be adjusted upwards to ensure successful establishment or downwards to save on seed costs. There will however be threshold values for the relevant species and it will be determined by whether coated or uncoated seed is used.

*Eragrostis tef* can be planted as a nurse crop with perennial species, especially *D. eriantha* and *C. gayana*. It is, however, important to focus on the successful establishment of the perennial species and it is recommended that weeds be controlled with herbicides rather than nurse crops if economically viable. By planting a nurse crop inter-species competition is created. Further research should be done on lowering the nurse crop seeding rate to determine if less inter-species competition and a more successful perennial establishment are possible.

It is advised to always do proper seedbed preparation, even if it proves to be insignificant in some situations. The effect of seedbed preparations evaluated under different field conditions regarding moisture availability, soil texture etc. will be of great interest.

When seed treated with any coating is planted, there is essentially much less seed being planted than in the case of uncoated seed at the same seeding rate (weight basis). The establishment success rate of the different seed treatments can be calculated by dividing the number of plants established by the number of seeds planted. In most cases, the coated seed treatments will have a higher success rate. It is still

unknown if this is due to establishment successfully facilitated by the seed coating, or if it is merely because of less seed being planted. This is, however, relevant since there will always be commercial interest in seed that gives the highest plant density at the lowest cost per hectare. For the current coating being used, the recommendation is to increase the seeding rate when using *D. eriantha* coated seed. The conventionally coated seed evaluated in this study, was superior to the Mycortex coating. However, only establishment success was evaluated. Growth performance of plants in field conditions should, in future, be compared between uncoated, conventionally coated and Mycortex coated seed treatments. Evaluation of the coated seed as opposed to uncoated seed by planting the same number of seeds per hectare can give insight on the influence of the coating substance on germination and the seeding rates to be used.