Establishment of *Urochloa brachyura* (Hack.) Stapf and its potential role in planted pastures and reclamation

by

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Submitted in partial fulfilment of the requirements for the degree

M.Sc. (Agric.) – Pasture Science

In the Faculty of Natural and Agricultural Sciences (Department of Plant Production and Soil Science) of the University of Pretoria
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Supervisor: Prof. N.F.G. Rethman

DECLARATION

I declare that this dissertation, which I hereby submit for the degree M.Sc. (Agric.) – Pasture Science at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at any other university.

______________________ ______________________

R.H. Roselt **Date**

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Abstract

Establishment of *Urochloa brachyura* (Hack.) Stapf and its potential role in planted pastures and reclamation

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Supervisor: Prof N.F.G. Rethman

Submitted in partial fulfilment of the requirements of the degree
M.Sc. (Agric.) – Pasture Science

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The selection and development of species adapted to extreme conditions is very important for sustainable production in South Africa. This is due to South Africa's limited natural resources, low and unpredictable rainfall, and ever-increasing human population. The need for an increase in livestock production, collapsing grain markets and the difficulty of profitable maize production, places more importance on the role planted pastures will play in the future. *Urochloa brachyura* is an annual tropical grass collected in Gauteng Province and selected for yield and quality. Seed harvested in 1999/2000 generally had a poor germination performance. This prompted an investigation into possible causes for poor germination and ways of improving seed quality. Investigating drying procedures, showed that drying temperatures between 20°C and 45°C did not have an effect on the quality of the seed. Several dormancy-breaking procedures were carried out with no success, although, applying a temperature treatment of 45°C for three weeks, increased germination to between 30 and 40%. It was found that emergence of seedlings where seed was covered with soil, was significantly better than the control which was not. The highest germination was found when seeds were planted 30 mm deep. Conducting a water stress experiment proved that water deficits had a definite negative influence on the dry matter production and the seed production of *U. brachyura* and can thus have a strong negative impact on the successful re-establishment of this annual species in water stressed conditions. A trial to evaluate dry matter production over three seasons was conducted in Pretoria. Representative samples were analysed for crude protein content and *in vitro* digestibility. The potential seed production was also evaluated over two seasons. Dry matter production results confirm results reported by Pieterse (1999), with an average total production of 14.3 t/ha, a digestibility of 74.9%, and a crude protein content of 12.3%. An average of 305kg seed/ha was produced over two seasons. The potential that *U. brachyura* already holds for use in rehabilitation practices because of its fast, low growing habit, was further evaluated by the determination of the influence of saline mine water on germination and dry matter production. The results suggest that *U. brachyura* can successfully be irrigated with saline mine water. It can be concluded from the results of this project that *U. brachyura* can be successfully incorporated in animal production systems and rehabilitation practices.

Uittreksel

Vestiging van *Urochloa brachyura* (Hack.) Stapf en die potensiële rol daarvan in aangeplante weidings en reklamasie

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Die seleksie en ontwikkeling van spesies aangepas in Suid Afrika se ekstreme toestande is baie belangrik vir volhoubare produksie. Dit is die gevolg van Suid Afrika se beperkte natuurlike hulpbronne, lae en onvoorspelbare reënval, en toenemende menslike bevolking. Die vraag na ‘n verhoging in diereproduksie, lae graan pryse en die gesukkel om mielies winsgewend te produseer, vergroot die rol wat aangeplante weidings in die toekoms sal speel. *Urochloa brachyura* is ‘n eenjarige tropiese gras, wat in die Gauteng Provinsie geselekteer is op grond van produksie en kwaliteit. Saad geoes in 1999/2000 was van lae kwaliteit met ‘n baie swak ontkiemings persentasie. Dit het ‘n ondersoek ontlok na die moontlike oorsake van die swak ontkieming, en hoe die kwaliteit van die saad verbeter kan word. ‘n Ondersoek na drogingspraktyke het gewys dat drogings temperature van tussen 20ºC en 45ºC nie die kwaliteit van die saad negatief beinvloed nie. Verskeie prosedures is gevolg in ‘n poging om dormansie op te hef, met min sukses. ‘n Temperatuur behandeling van 45ºC vir drie weke, het die ontkiemings persentasie verhoog na tussen 30 en 40%. Daar is ook gevind dat wanneer saad met grond bedek is, dat die ontkiemingspersentasie betekenisvol beter is as wanneer dit op die oppervlakte gesaai is. Die beste ontkieming is gevind waar saad 30 mm diep geplant is. ‘n Waterstremmings eksperiment het bewys dat water tekorte ‘n definitiewe negatiewe invloed op droëmateriaal produksie en saad produksie gehad het. Dit kan lei tot ‘n sterk negatiewe inpak op die suksesvolle hervestiging van dié eenjarige spesie met saad. Droëmateriaal produksie is bepaal oor drie seisoene in ‘n eksperiment wat in Pretoria uitgevoer is. Verteenwoordigende monsters van hierdie proewe is ontleed vir ru-protein en *in vitro* verteerbaarheid. Die potensiaal vir saadproduksie is ook oor twee seisoene evalueer. Die droëmateriaal opbrengs resultate het resultate verkry deur Pieterse (1999) bevestig. ‘n Gemiddelde droëmateriaal opbrengs van 14.3 t/ha, ‘n *in vitro* verteerbaarheid van 74.9%, en ‘n ru-protein inhoud van 12.3% is verkry. Daar is gemiddeld 305 kg saad/ha oor die twee seisoene geproduseer. Die potensiaal wat *U. brachyura* alreeds inhou vir gebruik in rehabilitasie praktyke, as gevolg van ‘n vinnige en laag groeiende groeiwyse, is verder ondersoek deur die invloed van sout myn water op die ontkieming en droëmateriaal produksie te bepaal. Daar is gevind dat *U. brachyura* suksesvol met sout myn water besproei kan word. Die gevolgtrekking kan dus gemaak word, na aanleiding van die resultate verkry, dat, *U. brachyura* wel geskik is vir die gebruik in diere-produksie en rehabilitasie praktyke.

Chapter 1.

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

Introduction Chapter – A review of the potential of annual sub-tropical grasses in agricultural production systems and land rehabilitation in RSA, with particular reference to *Urochloa brachyura* (Hack.) Stapf, and seed production.

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With the increase in human population in South Africa, less natural pasture is available for animal production. Furthermore, a large proportion of the land used for annual crop production in South Africa is marginal, resulting in low and variable yields. As a result, there is a growing interest in intensive grassland production in order to sustain the same, or even better, levels of animal production. When optimising pasture use, specific information on pasture production potential, pasture quality, and animal requirements are needed to ensure that monthly feed requirements of the animals match the monthly pasture production on the farm. In any feeding programme, definite periods of time can be identified where tropical annual grasses can supply the needed supplemental fodder. *Urochloa brachyura* is an annual tropical grass collected in Gauteng Province, selected for its high yield and quality. Annual tropical grasses are moderately to highly digestible and are readily consumed in the vegetative stage of growth by livestock. Because of its fast low growing habit *U. brachyura* also holds potential for use in rehabilitation practices. The seed of some tropical species can, however, be dormant and require additional development before germination can occur. Seed quality is an important consideration when establishing a pasture and the three basic parameters for quality are viability, vigour and purity.

Keywords: animal production, dormancy, germination, rehabilitation, tropical grasses.

Introduction

The role of planted pastures in South Africa.

South Africa has limited natural resources. The single most limiting factor to farming in general is the low and unpredictable annual rainfall. Approximately 65% of the country is arid or semi-arid, with only 28% of the country receiving more than 600 mm of rainfall per annum (Palmer & Ainslie 2002). Furthermore, a large proportion of the land used for annual crop production in South Africa is marginal, resulting in low and variable yields. Such land is better suited for the establishment of planted pastures.

Because of the increasing demand for protein by an ever-increasing human population, there is no alternative but to plan for a substantial increase in the amount of forage produced in South Africa as the basis for increased animal production. The productivity of agricultural land must, therefore, be increased without degrading the natural resources. One option to satisfy the ever-increasing demand for protein could be to increase livestock numbers on land set aside for animal production, but this provides only a short term solution to the problem, as the long term consequences of veld degradation and an increase in the rate of soil erosion resulting from overgrazing are inevitable. A move toward cultivated pastures and veld reinforcement or reclamation, would seem to be a requirement for any major increase in animal protein production. Not only should dry matter production be increased, but also the palatability, nutritive value and digestibility of the forage, which is produced by the modified sward. The development of this potential should make it possible to increase forage production to levels capable of supporting the necessary expansion of livestock numbers, and convert low yielding annual crop production sites to highly productive pastures. According to Tainton (2000) levels of milk, beef and mutton production will need to be increased by 34%, 22% and 56%, respectively within the next 20 years to meet the local demand. By making more land available for the establishment of pasture crops where possible, these objectives can be achieved. Such planted pastures may also play an important role in rendering degraded minelands productive.

Important considerations when selecting forage species.

When selecting a pasture grass species the main qualities desired are productivity, palatability, nutritive value, and adaptation to the local soil and climatic conditions. The aims of pasture use (e.g. the type of animal production, the importance of pasture-crop interaction or the necessity for watershed stability) will decide the importance of various pasture qualities (Humphreys 1982). The new species must bring significant advantages in at least one characteristic in comparison with the existing species. These advantages could, for instance, be higher yields or supplementary green fodder at a time when it is scarce (Bayer & Waters-Bayer 1998).

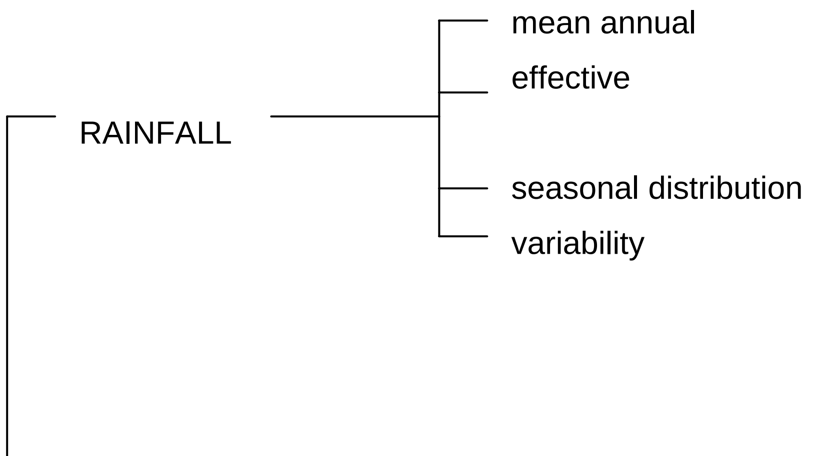
According to McIlroy (1972) the productivity, or yield, of a pasture species depends on the following characteristics:

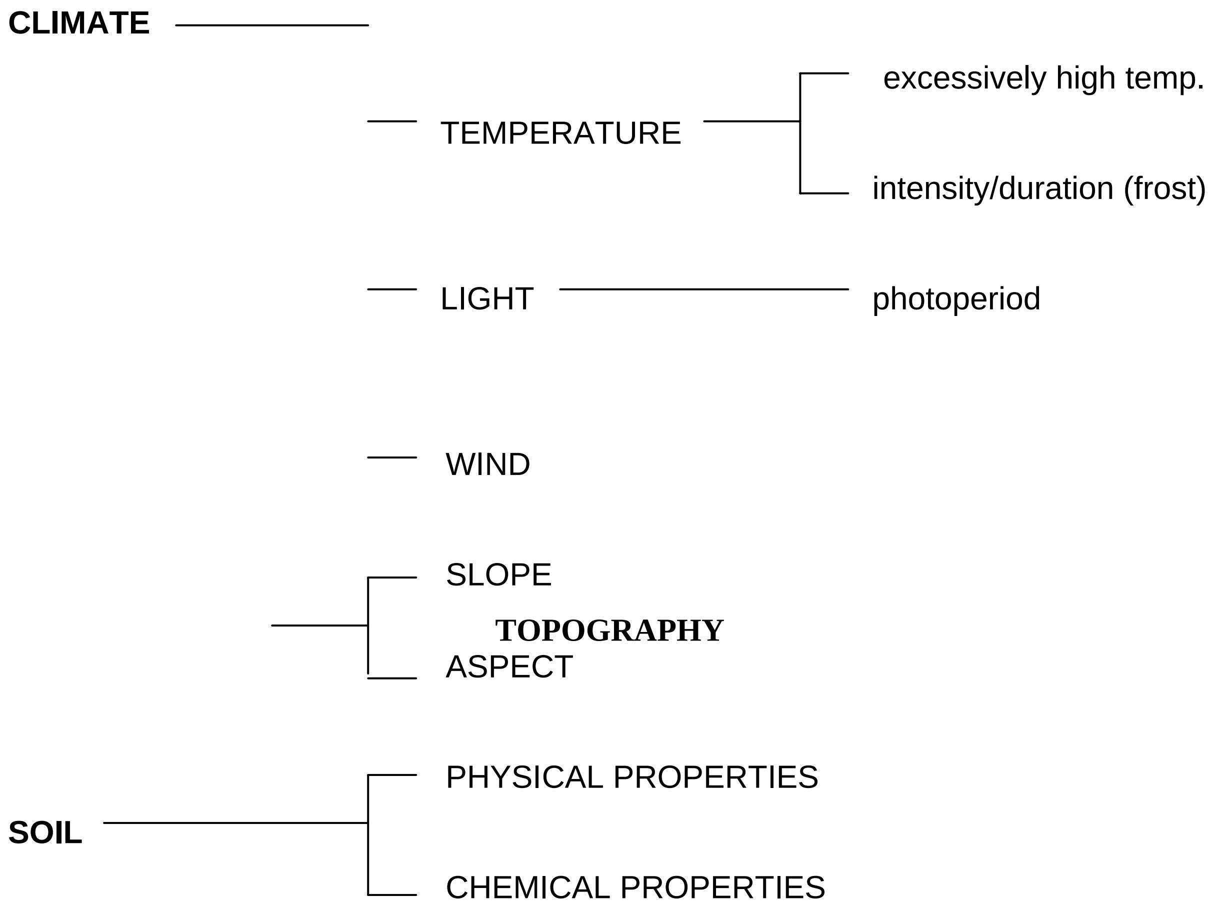
(a) Persistence, or the ability to survive and to spread by vegetative methods;
(b) Aggressiveness, or the ability to survive the competition of other associated species;
(c) The ability to recover from heavy grazing and trampling;
(d) Drought-resistance and tolerance to cold;
(e) Seasonal distribution of production;
(f) The capacity to produce a good yield of viable seed, or to be established cheaply by vegetative propagation;
(g) Soil fertility (especially nitrogen level);
(h) Climate

The palatability of a pasture was defined by the Society of Range Management as the “relish with which a particular species or plant part is consumed by the animal”(Jacoby 1989). Mentis (1981) defined palatability more specifically as “Those factors of the feed itself that determine the absolute attractiveness of the feed to the animal”. McIlroy (1972) described palatability as the connecting link between grass and the grazing animal, and that it is regarded by many authors to be of greater importance than nutritive value. McIlroy (1972) stated further that it has been demonstrated frequently that cows prefer indigenous grasses to selected varieties of grass, despite the fact that the indigenous grasses may be lower in productivity and nutritive value.

Nutritive value describes the concentration of nutrients in a feed, and is assessed in terms of the protein content, energy availability, minerals and vitamins, and the absence of toxins (Humphreys 1982). The most important factor determining animal output is the amount of forage ingested, and the proportion digested by an animal. If no deficiencies of minerals or protein exist and they are in adequate supply, the animal performance will depend on the energy level of the forage (Humphreys 1982). Intake can vary considerably between species and between cultivars. For example species having a dense sward structure provide a larger intake per bite than loose, trailing species (Humphreys 1982). Tropical grasses are generally low in crude protein and high in crude fibre when compared with temperate grasses cut at similar stages of growth. The dry-matter yield of tropical species also tends to be much higher than that of temperate species (McIlroy 1972). The primary deficiency during winter in subtropical grasses is thus protein and not energy. During summer the opposite is true and an energy deficiency often occurs, because of the low dry matter content of green and succulent forage (Tainton 2000). Other factors that also affect the nutrient value of a pasture species are the leaf/stem ratio, the stage of growth at cutting or grazing, the soil fertility and manurial treatment, and the climatic conditions (McIlroy 1972).

Through the years different species have become adapted to certain environmental conditions. These factors are also very important considerations when selecting a species for a particular area. Tainton (2000) summarized the most important environmental factors, as follows:





With a mean annual rainfall of approximately 450mm, South Africa is regarded as semi-arid (table 1). Wide regional variations in annual rainfall occur, from as little as 50mm in the Richtersveld on the border with Namibia, to more than 3000mm in the mountains of the southwestern Cape (fig. 1)(Dent *et al.* 1987). It is not only the total annual rainfall of an area that is important but also the mean monthly distribution. This data is important as some areas often receive most of their total annual precipitation within two months and are then dry for the rest of the year. This uncertainty can best be expressed by the co-efficient of variation in annual rainfall (fig. 2)(Palmer & Ainslie 2002). South Africa can be divided into three major rainfall regions, namely the winter rainfall region of the western, south western and southern Cape; the bimodal rainfall region of the Eastern Cape, and the strong summer seasonality of the central highveld and KwaZulu Natal (Palmer & Ainslie

2002). Dannhauser (1985) emphasized the importance of genetic adaptability of different species. He used the example of *Anthephora pubescens* and *Cenchrus ciliaris*, which can be established in low rainfall areas (<500mm), and *Pennisetum clandestinum* that prefers high rainfall areas (>700mm).

Table 1. Annual rainfall distribution and climatic classification in South Africa

Rainfall (mm)	Classification	Percentage of land surface
<200	Hyper-arid	22.8
201-400	Arid	24.6
401-600	Semi-arid	24.6
601-800	Sub-humid	18.5
801-1000	Humid	6.7
<1000	Super-humid	2.8

Source: Schulze 1997

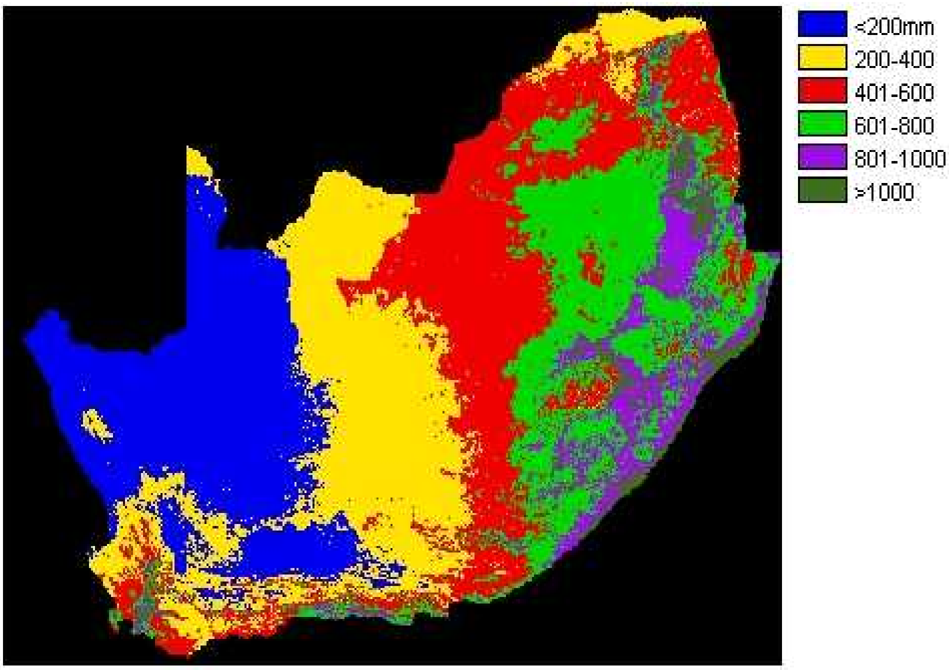


Figure 1. The median annual rainfall for South Africa (Dent *et al.* 1987)

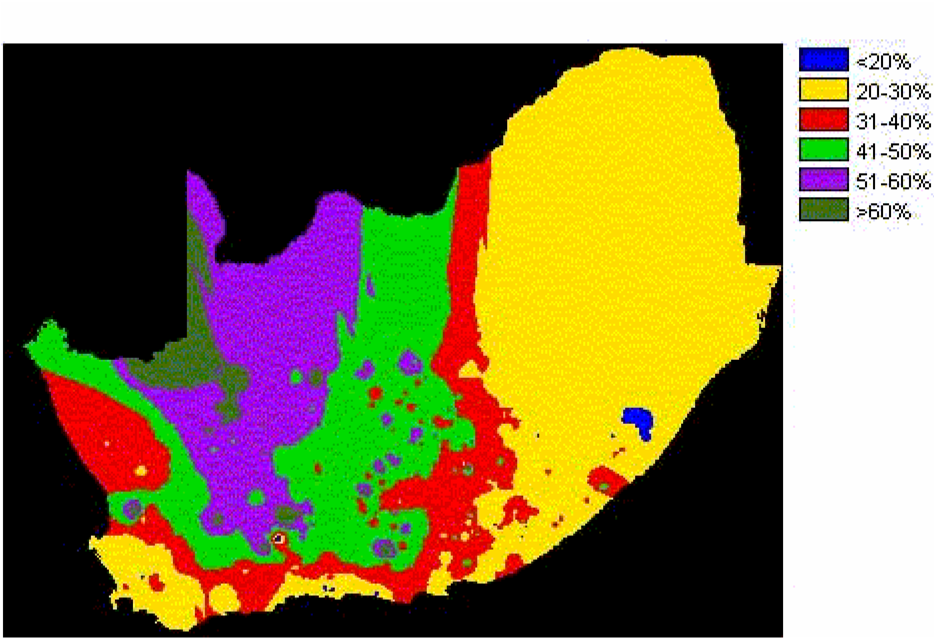


Figure 2. The co-efficient of variation in annual rainfall for South Africa, derived from the long-term rainfall records (50 years or more data) from 1015 stations (Palmer & Ainslie 2002)

In contrast to temperate grasses, which have an optimum temperature range of about 15-20°C, tropical grasses are all adapted to warm environments. Their maximum growth rate usually occurs at high temperatures, about 35°C (Humphreys 1982). Humphreys (1982) also stated that, although growth rates of tropical grasses are high under hot conditions, their digestibility decreases as temperature increases. Some grasses are very sensitive to low temperatures and frost. According to Dannhauser (1985) *Cynodon nlemfuenses* should not be planted in areas receiving heavy frost. He also states that *Lolium perenne* is sensitive to high summer temperatures, and could have an increased longevity if planted in areas having cooler summers. According to Humphreys (1982) grasses like *Paspalum dilatatum, P. notatum, P. clandestinum,* and *Setaria anceps* possess some cold tolerance. On the other hand, grasses like *Digitaria decumbens* cease growth when night temperatures fall to 11°C, irrespective of the level of day temperatures. This is due to the continued accumulation of starch in the leaves during cool nights, which causes injury to the chloroplasts on which photosynthesis depends (Humphreys 1982). Temperature is thus a major consideration in terms of production and adaptability when selecting a pasture grass.

Light, and more precisely photoperiod, determines when flowering and seed production occur (Humphreys 1982). Plants can be grouped into three categories based on their flowering response to daylength:

(a) "long-day" (short night) plants. Cool season grasses fit into this category. These plants flower during spring when daylength is increasing.

(b) "short-day" (long night) plants. These are plants that only flower in summer or early autumn when daylength is decreasing.

(c) "day-neutral" plants. Plants that may flower throughout much of the growing season.

(Ball *et al*. 1996)

Grasses like *P. dilatatum* and *P. notatum* are long-day plants. They flower in the early summer and warm temperatures hasten their flowering. Most tropical plants flower in response to shortening days, e.g. *Paspalum plicatulum* (Humphreys 1982).

Topography and soil also have a major influence on the production potential of an area. Topography can be described as the terrain morphology of an area. This could best be described by the soil catena concept where a typical landscape can be divided into six categories, comprising crest, free face, middle slope, foot slope, wet toe-slope and alluvium. Soil on the crest and middle slope are usually shallow due to water flowing away from these areas. This lead to soils being deeper, wetter, and more fertile on the lower areas such as the foot slope and wet toe-slope. Aspect describes the direction to which the slope faces, and affects the growth temperatures. In South Africa light is more concentrated on the northern slopes than on the southern slopes. Northern aspects are, therefore, hotter and consequently drier than southern aspects in the Southern Hemisphere (Tainton 2000). Different grasses prefer different types of soils. A grass like *Eragrostis curvula* would prefer a well-drained fertile soil, while *Chloris gayana* prefers loamy soils. *C. ciliaris,* on the other hand, grows best in well-drained sandy soil (Van Oudtshoorn 1999). In order to choose the species best adapted to a particular soil, the chemical, as well as the physical, properties of the soil should be considered.

By investigating all the abovementioned factors, the best possible species, in terms of productivity, nutritive value, and adaptability, can be selected for a particular area. By doing this, problems such as poor persistence, aggressiveness and poor production of a pasture could be eliminated, or at least minimized.

The role of sub-tropical annual grasses in fodder flow planning

Making money from livestock usually depends on the farmers' ability to produce their own feed. Buying forages, even for short periods of time, can make the difference between a profit and a loss. Feed planning helps to ensure that pasture use is maximized, either directly by grazing or, where profitable, indirectly by cutting for conservation. Optimising pasture use requires specific information on pasture production potential (in kg DM/ha/month and year), pasture quality (in MJ metabolizable energy per kg dry matter (MJ ME/kg DM), and animal requirements (in kg DM/animal/month/year) (Van Houtert & Sykes 1999). This information could then be used as a management tool to ensure that monthly feed requirements of the grazing herd match the total monthly pasture production on the farm as closely as possible (Cros *et al*. 2001). Inevitably, periods of pasture deficit will arise, and this is where sub-tropical annual grasses could be of importance to fill such gaps.

Teutsch (2002) states that cool-season grasses in Virginia produce ample forage in the spring and fall, but high temperatures and short-term drought stress often limit growth during the summer months. Therefore, during July and August there is a need for additional grazing, hay or green-chop. Warm-season annual grasses can fit this gap with relatively high quality forage when properly managed (Teutsch 2002). According to Bates (2002) livestock production in Tennessee is based on cool-season perennial forages such as Tall fescue and Orchard grass. These grasses are productive during the spring and fall, but become semi-dormant during the summer months. The need for quality forage during this time of the year can be met by using annual summer grasses.

Kramer & Johnson (2002) state that shortages of forage most often occur during summer in Indiana, as perennial cool-season grasses become semi-dormant during the hot summer months. During this period, cool-season grasses produce very little growth and shortages can quickly occur if moisture is inadequate. Maintaining proper herd size, renovating pastures with legumes, fertilizing according to soil tests, and utilizing a rotational grazing system can help reduce summer forage shortages. During years of below average rainfall, however, there can still be a risk of having a short supply of food.

According to Dorsett & Warrick (2000) annual summer grasses also often form part of the total forage program for many livestock producers in Texas, and are used to provide high-quality forage for grazing in mid-summer when perennial grasses are low in yield and/or quality. Annual summer grasses can, therefore, provide high quality forage at a time when it often cannot be supplied any other way, and for this reason should be part of the total forage program (Dorsett & Warrick 2000). By resting cool season perennial pastures and using summer annual

grasses in these areas, these stands are more persistent and could supply more fall grazing (Coblentz & Phillips 2000).

In South Africa the most commonly grown annual subtropical grasses are *Eragrostis tef, Pennisetum glaucum,* and *Sorghum spp*. (Dannhauser 1985). The main purposes of these crops are the production of hay and silage, although they could also be incorporated into grazing systems. These grasses can provide high yields of good quality forage in a relatively short period. Perennial subtropical grasses in South Africa, which are responsible for most of the summer grazing, have their peak production during mid summer. During spring and fall feed shortages could still, therefore, occur. According to Tainton (2000) the most difficult periods of the year for livestock in the semi-arid summer rainfall areas are late winter, spring and early summer. During this period crop residues will generally already have been fed to the livestock and land preparation for spring planting will have commenced. In the non-cropping areas forage accumulated during the previous season will often have been fully utilized during winter. Fodder conservation during the growing season is, therefore, of utmost importance to carry over animals from winter to when ample fodder is again available in summer. Tainton (2000) also advised that it is essential that hay be available at all times to buffer the forage system, as the extremely variable summer-growing conditions in South Africa cause pasture growth rates to vary considerable over the season. In the sourveld areas there is often a deficiency of pasture with good quality in the autumn / early winter period, when crop residues are not yet available. The provision of foggage from sown pastures would seem to be the most cost-effective means of bridging this feeding period on most farms, as it eliminates the need for mechanical harvesting (Tainton 2000). Tainton further stated that planted pastures are unlikely to be able to support viable livestock production systems on their own in the semi-arid regions because of their relatively high cost and their unreliable seasonal production, but their main value generally lies in their ability to provide forage during strategic periods of the year. There are, therefore, definite periods of time in a feeding programme, where annual subtropical grasses can be used to supply the needed supplemental fodder.

Description of the most important sub-tropical annual grasses

Eragrostis tef (Teff)

Figure 3. Eragrostis tef

Teff is a tufted, summer growing annual, tropical to sub-tropical C4 grass. Teff grows 200-900mm tall and produce thin, soft and hairless leaf blades. It is an exotic grass that only occurs in disturbed places. The entire plant is light green when young, and flowers from November to May in South Africa (Van Oudtshoorn 1999). Teff is often planted on cultivated lands and along new roadsides. It grows well on most types of soil, but is not adapted to waterlogged conditions (Dickinson *et al*. 1990). Teff is usually established under dryland conditions in the summer rainfall areas of South Africa. Teff can be planted in areas with seasonal rainfall ranging from 300 to >1000mm (Engels *et al.* 1991). According to Cheverton & Chapman (1989) some fast growing types can grow with as little as 150mm of seasonal rainfall. Photosynthetic leaf processes seem to be most active in the temperature range 35-42°C (Kebede *et al.* 1989).

Teff also grows well at lower temperatures, but is not frost tolerant (Cheverton & Chapman 1989). Teff is mainly planted for hay production in South Africa, and is seen as the ideal hay crop due to its fast curing rate and quality. Teff may be planted from the beginning of September, depending on the first good spring rain, to at least the end of January. However, the later the planting the fewer the number of cuts that can be obtained and consequently the lower the total production. Depending on the planting date, the first cut can be obtained as early as 50 days after sowing (Kassier 1999). The thin stem structure of the grass makes it a popular source of fodder for horses. It is also often planted as a cover crop to prevent erosion. In South Africa teff is also used as a "nurse crop" that quickly covers the ground and fosters the establishment of perennial grasses sown with it. These mixtures can be planted to protect road cuts, opencast mine workings, stream banks, and other erodible sites (Kassier 1999).

***Sorghum bicolor* (Forage sorghum)**

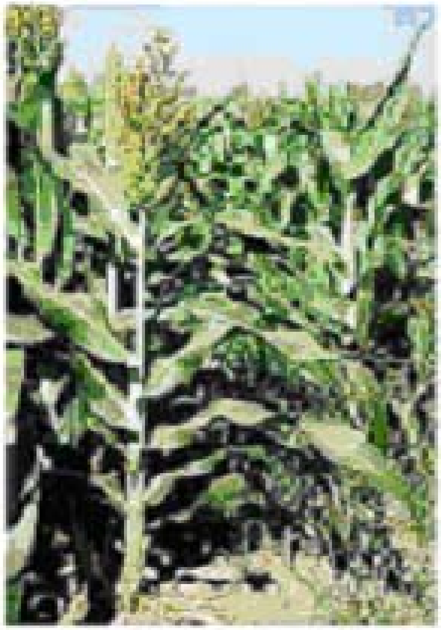


Figure 4. Forage sorghum

Sorghum is a coarse, upright annual growing grass that is used for both grain and forage production (figure 4). Grain sorghum is shorter and has been bred for higher grain yields. Forage sorghum grows from 180 – 450 cm tall and produces more vegetative growth and less grain. Sorghum grows best on well-drained, fertile soils that have a good water holding capacity. Forage sorghums generally perform best when the soil pH ranges from six to seven (Teutsch 2002). In most cases, sorghums are harvested once per season as either green – chop or silage, but can also be grazed or hayed. Typically, forage sorghums are harvested for silage when grain is in the mid-to-late-dough stage. The moisture content at harvest should preferably be less than 70 percent to ensure proper fermentation and to prevent excessive effluent losses (Coblentz & Phillips 2000). The primary advantage of utilizing sorghum for silage production is its good drought tolerance. Silage yields are similar to those of maize, allthough sorghum is slightly less palatable and digestible than maize silage (Teutsch 2002). Forage sorghums are sometimes cut for hay, although drying and curing may be difficult or slow in humid climates. According to Fribourg and Waller (2001) two to five harvests can be attempted during the growing season, each having a potential yield of two tons dry material per hectare or more. Utilizing sorghums as green chop allows for maximum management control and efficient use of resources but also limits feed selection by animals while minimizing forage waste. According to Fribourg and Waller (2001) the summer feeding of green chopped material for lactating cows is a common practise in intensive dairy enterprises, which provides the cows with high quality forage. Pasturing is the cheapest method of harvesting forage, although efficient utilization of fast growing summer annuals demands considerable attention. Due to the ability of animals to graze selectively, they may produce more milk or meat than when fed the whole plant. However, grazing leads to waste by trampling or fouling by excreta (Fribourg & Waller 2001).

Sudan grass (*Sorghum spp.*) and Sorghum-Sudan grass hybrids

Sudan grass is a tall, leafy annual grass belonging to the sorghum family (figure 5). Sudan grass has been used extensively in the past, but has declined in popularity with the development of Sorghum-Sudan grass hybrids. True Sudan grass possesses fine stems and regrows rapidly after grazing. Sudan grass is adapted to practically all soils except those, which are very wet and poorly drained, or those that are extremely alkaline or sandy.

Figure 5. Sudan grass

The soils generally favourable to Sudan grass are similar to those favourable to other sorghums. Adequate germination should occur when the soil temperature ranges between 20 and 30° C. The crop should be planted about 35 days before grazing is needed (Coblentz & Phillips 2000). Sudan grass is best used for pasture or in multiple cut systems (McKinlay & Wheeler 1998).

Figure 6. Sorghum-sudan grass

Crossing sorghum with true Sudan grass develops Sorghum-Sudan grass hybrids (figure 6). The result is a tall growing annual grass that resembles Sudan grass, but has coarser stems, taller growth habit, and higher yields. Like Sudan grass, hybrids will regrow after grazing if growth is not limited by environmental factors. Sorghum-Sudan grass hybrids like Sudan grass are best adapted to well-drained, fertile soils. These grasses do not tolerate low pH and require liming when grown on acid soils. Hybrids are excellent choices for either green chop or silage, but can be grazed as well (Coblentz & Phillips 2000).

Figure 7. Babala

***Pennisetum glaucum* (Babala, Pearl millet)**

Babala (figure 7.) is another annual warm-season grass that exhibits growth characteristics similar to Sudan-grasses and Sorghum-Sudan grass hybrids, although it technically belongs to a different genus. Babala has smaller stems and tends to be leafier than forage sorghum, Sudan grass, and Sorghum–Sudan grass hybrids. It typically ranges from 90 – 240 cm in height. A primary benefit of Babala is that it does not contain prussic acid (Teutsch 2002), a feature in many Sorghum cultivars. Babala is also better adapted to more acid soils and soils with a lower water holding capacity than Sorghum, Sudan grass or Sorghum-Sudan grass hybrids. A pH of 5.5 to 6.5 is required for maximum production. Babala is, however, more sensitive to cold stress than Sorghum and may be killed by low temperatures in early spring when Sorghum is not. It should be planted when the soil temperatures have reached at least 20°C (Teutsch 2002). Babala grows rapidly and will provide grazing in as little as 45 to 60 days. Babala can be cut for hay, ensiled, used for green-chop, or grazed. Grazing can be initiated when plant height reaches 30 – 45 cm. It can be harvested for hay when it reaches 60 – 120 cm. Babala can be direct ensiled when the grain has reached the soft dough stage (Teutsch 2002).

Quality characteristics of the most important annual sub-tropical grasses

Annual summer grasses are moderately to highly digestible. With good management, the performance of animals fed the different types of annual summer grasses is similar. They are readily consumed in the vegetative stage of growth by livestock, when the total forage mass has a large ratio of leaves to stems, large concentrations of protein and digestible nutrients, and small amounts of fibre and lignin. Lignin concentrations increase with advancing maturity, resulting in reduced animal intake and decreased digestibility. The digestibility of young leaves may approach 75% dry matter digestibility, while older leaves may be only 50 to 60% digestible and culms may be as low as 30 to 50% digestible (Fribourg & Waller 2001). Table 2. contains quality data on the most important annual summer grasses.

Table 2. Dry matter content, crude protein, and total digestible nutrient values for the most commonly used annual sub-tropical grasses.

Feed Identification	Dry Matter %	Crude Protein %	%Total Digestible Nutrients
Dry Roughages			

[1]Pearlmillet hay	90	8.5	61
[1]Sorghum fodder	85	7.4	65
[1]Sudan grass hay, early bloom	89	11	56
[1]Sudan grass hay, mature	90	6.6	48
[2]Eragrostis tef	90	12.1	52.3
Silages			
[1]Sorghum silage	30	8.1	58
[1]Sudan silage, immature	25	16.8	59
[1]Sudan silage, early bloom	28	11.3	55
[1]Sudan silage, mature	30	6	48
[1]Sudan-Xsilage	25	8.7	49
Grazed Forages			
[1]Pearlmillet, leaves	20	13.7	61
[1]Pearlmillet, stems	20	9.9	61
[1]Sudan grass, leaves	20	17	59
[1]Sudan grass, stems	20	7.2	59

[1]Taken from: Stock *et al*. 1995.

[2]Taken from: Van der Merwe 1970.

Urochloa brachyura

Description of *Urochloa brachyura*, and its potential for animal production and mine rehabilitation.

U. brachyura is a tufted, annual tropical grass, native to South Africa. It was selected for its high yield and quality characteristics in the Gauteng province (Pieterse 1999). It produces an abundance of leafy material and has a fast low growing habit (fig. 8).

Figure 8. *U. brachyura* in the active growing state illustrating the abundance of leafy material produced.

Gibbs Russell *et al.* (1990) describe *U. brachyura* as an annual, growing 200-1200mm high, which flowers form October to April. It is adapted in Savanna, Grassland and Nama-Karoo biomes. *U. brachyura* most often occurs in bushveld and grassland areas on clay soils, and often in shade (Van Oudtshoorn 1999). *U. brachyura* is closely related to *U. oligotricha*. The latter is a perennial, less hairy and has more racemes per inflorescence (Van Oudtshoorn 1999).

The de-awned fertile floret of *U. brachyura* consists of a lemma and a palea closely enclosing the caryopsis (figure 9). At the lower end of the lemma there is a raised semi-elliptical flap, which at germination is broken open by coleorhizal hairs which grow out in a clump, followed by the radicle.

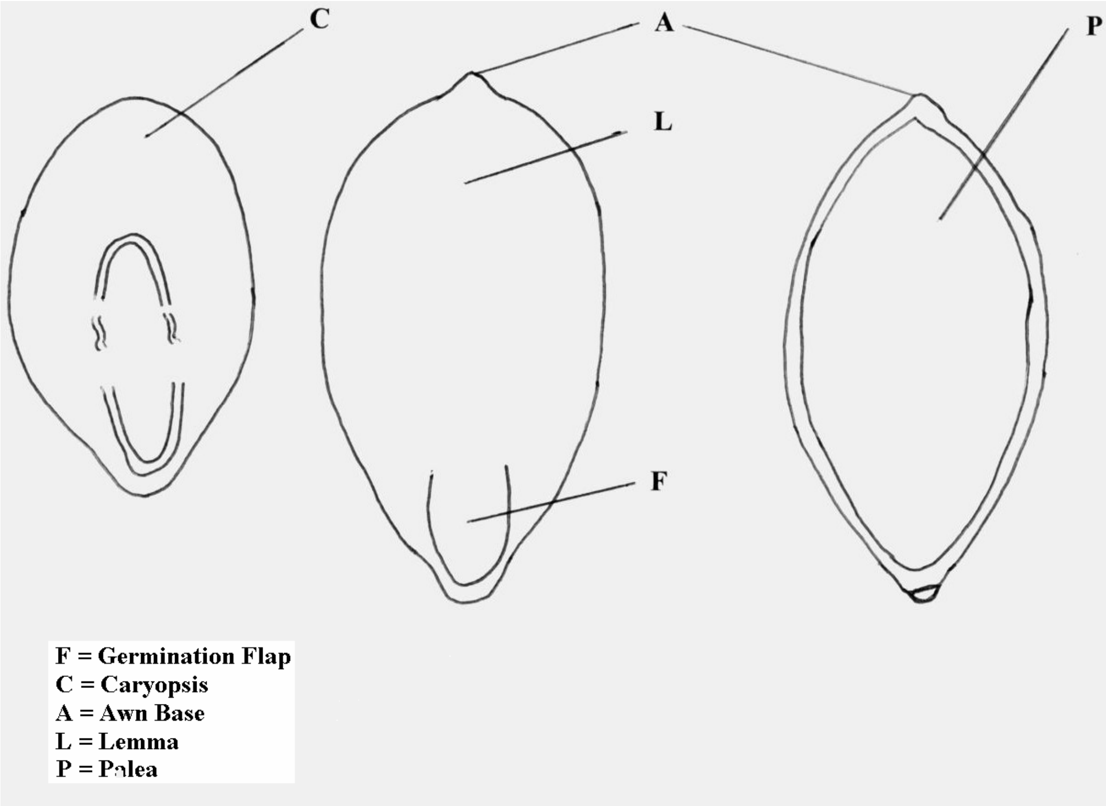


Figure 9. Florets and Caryopsis of *U. brachyura.*

Only in rare cases are cultivated forages the sole or major source of forage, due to the fact that planted pastures are relatively expensive. They are thus used in combination with crop residues and natural forages and must be seen in the context of the entire system of forage husbandry. The main function of forage cultivation is, therefore, to fill gaps in forage supply, and to increase production. Pieterse (1999) identified *U. brachyura* as having great potential for use in animal production systems. He found *U. brachyura* to have a digestibility of +- 82%, with a crude protein content of +-10.7%. This characteristic, together with its low growing habit makes *U. brachyura* suitable to be grazed by cattle as well as sheep. *U. brachyura* has furthermore, a potential dry matter production of more than 15 t/ha. Because it is an annual, it may also have potential for use in rotational practices where it can produce high quality forage over a short period of time. Mine rehabilitation is another area in which this species shows great promise. Here the main aim is to stabilize the land with vegetation, by establishing a good ground cover as quickly as possible, to reduce surface erosion on steep slopes and to control water runoff. *U. brachyura* is a native species, fast and low growing, and can produce a quick cover to bind the soil. It, therefore, holds great potential to be used in rehabilitation.

Seed Quality

Seed quality is defined firstly by the proportion of seeds which will germinate to form healthy plants and secondly by the freedom of the seed from contamination by seeds of different genetic constitution, by inert material or by pests or diseases (Bradbeer 1988). The three basic parameters for seed quality are viability, vigour and seed purity (Bradbeer 1988). Neither buyer, nor seller, of seed can accurately assess seed quality from appearance alone. Recognised methods of seed quality examination have, therefore, been developed, and seed testing has become standardised throughout the world. Seed testing provides information on the physical and physiological quality and behaviour of seed lots. South Africa has in the past relied heavily on imports for its supply of forage-grass seed. Locally produced seed yields and seed quality have generally been poor due to the fact that this seed has largely been a by-product of the livestock industry rather than the product of the planned production of a seed crop. Good quality seed and yields can, however, be obtained from dual purpose pastures if certain basic principles concerning the management of the pasture as well as harvesting techniques and seed treatment prior to storage, are implemented (Tainton 2000).

Seed drying

Freshly harvested seed, and in particular seed which has been combined directly, will normally be reasonably moist. Such seed will dehydrate rapidly if it is not dried sufficiently before it is stored. According to Tainton (2000) freshly harvested seed, stored in sacks or bins, may heat sufficiently to cause permanent damage within as little as one hour. Seed should, therefore, be dried as soon as it has been harvested.

Partridge (1996) stated that all seed harvested with a moisture content too high for storage, needs careful handling because it is metabolically active, and that grass seed is much more vulnerable than seed of cereals and pulses that are harvested dry. Most seed would, therefore, continue to produce both heat and waste gasses, as it is still metabolically active, and these could kill or suffocate the seed if not dissipated. Large amounts of freshly harvested seed are very susceptible to suffocation, especially if the seed has been harvested at a high moisture content and packed tightly. Seed should, therefore, be ventilated as soon as possible (within a few hours) and should never be allowed to heat up to a temperature where the hand cannot be kept comfortably buried in the bulk (45 – 50ºC). Freshly harvested seed could have a moisture content as high as 60 %. For safe storage, for relatively short periods (up to 12 months), the moisture content of the seed needs to be reduced to about 13 to 14 %. For longer periods of storage, further drying to a moisture content of about 10 % is advisable (Tainton 2000).

Humphreys and Riveros (1986) stated that it is expected that seed will ferment at 18 to 20 percent water, grow moulds at 12 to 14 percent, but that at 8 to 9 percent water insect activity will cease. Some seed producers rely on sun drying, which can be dangerous for seed, or on natural drying on a smooth shed floor where a shallow layer of seed may be frequently turned to avoid heating.

In humid environments, artificial drying equipment that is not dependent on the weather is essential and will provide better control of seed quality. Artificial drying procedures, when improperly applied, could also produce seed lots that lose their viability in storage with unusual speed (Harrington 1972). Various types of dryers have been developed or adapted from other crops in the past (drum-tumblers, seed-circulating systems, air-recycling methods) but the best is the simplest – the bin dryer.

Due to South Africa's hot and dry climate, seed can effectively be dried without expensive artificial dryers and the latter would, therefore, often not be economically viable.

Viability

A viable seed is one that is capable of germinating under suitable conditions. The definition includes dormant but viable seeds, in which case the dormancy must be broken before viability can be measured by germination. Seeds that fail to germinate even under optimal conditions (including treatments for the removal of dormancy) are, therefore, non-viable seed (Bradbeer 1988). Humphreys and Riveros (1986) stated that seed viability is, therefore, the term that describes the proportion of seeds that are alive and may be expected eventually to germinate. Copeland and McDonald (1995) also described viability as denoting the degree to which a seed is alive, metabolically active, and possessing enzymes capable of catalysing metabolic reactions needed for germination and seedling growth. After physiological maturity, the viability of seeds gradually declines, and their longevity depends on the environmental conditions to which they are exposed. Assessing seed viability is thus an excellent tool in predicting potential seed germination, and is therefore useful in many respects. Viability can be very rapidly assessed by cutting the seed open and staining with tetrazolium (Copeland & McDonald 1995). Harty *et al*. (1983) found that seed of *P. maximum* reached its maximum germination after 200 days of storage, and this figure was well correlated with the viability of the seed, as indicated by a tetrazolium test at the beginning of storage. Rocha *et al.* (1977) obtained similarly good agreement.

Tetrazolium testing, which has been developed to furnish quick estimates of seed viability, is useful in facilitating the buying and handling of seeds, testing dormant seed lots, preliminary testing in seed control work, rating seed lots for vigour, supplementing germination tests, and diagnosing causes of seed deterioration (Grabe 1970). The tetrazolium test distinguishes between viable and dead tissues of the embryo on the basis of their relative respiration rate in the hydrated state. The test utilizes the activity of dehydrogenase enzymes as an index of the respiration rate and seed viability. The dehydrogenase enzymes release hydrogen ions as they react with substrates. These ions change the oxidized, colourless, tetrazolium salt solution into red formazan. Seed viability is then interpreted by the topographical staining pattern of the embryo and the intensity of the coloration. The live and dead areas of the embryo are revealed by the coloration and enable the analyst to determine if seeds have the capacity to produce normal seedlings. The tetrazolium test procedure follows the following four steps:

(a) Preconditioning–seeds are hydrated.
(b) Seed preparation – seeds are cut or pierced to facilitate entry of the tetrazolium solution into the embryo.
(c) Staining–seeds are placed in a tetrazolium solution (usually 1.0 or 0.1%)
(d) Evaluation - evaluation of staining pattern (McDonald *et al.* 1992).

The tetrazolium test is the most commonly used test to determine seed viability, and, together with the germination test, is the most effective way to assess seed quality.

Germination

The eventual function of the surviving seed is its germination, followed by the growth of the embryo to give a mature plant. Germination can be defined as the emergence of the radicle through the seed coat (Copeland & McDonald 1995). According to Bradbeer (1988) germination is complete when all of the seeds available food reserves have been consumed and the seedling is capable of independent existence. Two types of germination occurs, based on the fate of their cotyledons or storage organs. During epigeal germination, the cotyledons are raised above the ground where they continue to provide nutritive support to the growing points. During hypogeal germination, the cotyledons or storage organs remains beneath the soil while the plumule pushes upward and emerges above the ground. The cotyledons continue to provide nutritive support to the growing points throughout germination. The coleoptile, a temporary sheath enclosing the plumula and associated with hypogeal germination, provides protection and rigidity to the emerging plumula as it pushes through the soil. It then stops growing and disintegrates as the plumula breaks through and continues to grow. This type of germination is associated with many species including grasses. (Copeland & McDonald 1995).

For germination to occur, certain physical conditions are required, and according to Bradbeer (1988) these are:

(a). Water. All seeds require sufficient moisture for inbibition and germination and most will germinate well even when supplied with a clear excess of water. Copeland and McDonald (1995) stated that water is the basic requirement for germination, and essential for enzyme activation, breakdown, translocation, and use of reserve storage material.

(b). Temperature. Germination involves many individual reactions and phases, each of which is affected by temperature. Each species has a range of temperatures at which germination will occur and at which seedling establishment is possible. The optimum temperature for most seed is between 15 and 30ºC and the maximum temperature between 30 and 40ºC.

(c). Oxygen. Imbibition can occur in the absence of oxygen, but for most seeds the remaining stages of germination are inhibited under anaerobic conditions and can result in seed death. Oxygen is the terminal electron acceptor in respiration, and inadequate oxygen inhibits the respiration necessary for the germination of most seeds and also results in an accumulation of potentially toxic products of anaerobic respiration, such as acetaldehyde, ethanol and lactate.

The ability of seed to germinate is probably the single most convincing and acceptable index of seed quality. A seed lot is composed of a population of individual seed units each of which possesses its own distinct capability to grow and produce a mature plant. Seed lots are, therefore, tested for germination. A seed germination test is an analytical procedure to evaluate seed viability and germination under standardized conditions. It can provide important information to the consumer in terms of seed quality before it is marketed. Furthermore, the percent germination can be used to determine the planting value of a seed lot, its storage potential, and labelling information required to provide for standardized marketing of seed lots (Copeland & McDonald 1995).

The exact procedures, instructions and regimes under which different kinds of seeds are germinated, are given in the Rules for Seeds which have been developed over 100 years of experience in germination testing by the association of Official Seed Analysts (AOSA 1991). These testing instructions include the germination media, the temperature required, the duration of the test period, and additional suggestions for optimal results (AOSA 1991). A minimum of 400 seeds is recommended for a statistically dependable germination test. Seeds are usually planted in four replicates of 100 seeds each, although various other arrangements are sometimes used. Each replicate is evaluated separately, but the official germination report is an average of all replicates. The time required for germination tests varies among species. Some seeds require less than seven days, while others may require a month or longer. Evaluations are made at the end of the prescribed germination period, although preliminary evaluations, called first counts, are sometimes made. At the first count seedlings that have germinated, and are normal, are counted and removed from the substrate to make subsequent counts easier as early-germinating seedlings often tend to grow profusely, causing difficulty in evaluating later-germinating seedlings. Seeds that remain ungerminated at the end of the prescribed period are considered dead or dormant (Copeland & McDonald 1995).

Dormancy

According to Copeland and McDonald (1995), during the germination test procedure, seeds can be classified into four categories namely:

Normal seedlings – Seed capable of producing normal plants under favourable conditions.
Abnormal seedlings – Any seedling that is not classified as a normal seedling is considered abnormal.
Firm, ungerminated (dormant) seeds – Seeds other than hard seeds that remain firm (nondecayed) and ungerminated at the end of the prescribed germination period are called firm, ungerminated seeds. This is a type of dormancy commonly found in certain grasses, and should be treated appropriately to simulate germination

Hard seeds – Hard seeds are those that do not imbibe water and therefore remain hard at the end of the prescribed germination period. Hard – seededness is a type of dormancy that prevents germination of viable seeds because they cannot absorb water through their impermeable seed coat.

Some seeds are capable of germinating only days after fertilization. Other seeds can be dormant and require an extended rest period or additional development before germination can occur. This period can vary between only a few days, to as long as several years depending on the species (Copeland & McDonald 1995). Copeland and McDonald (1995) describe true dormancy as a state in which seeds are prevented from germinating even under environmental conditions normally favourable for germination. They state further that several physical and physiological mechanisms of dormancy, including both primary and secondary dormancy, occur in seeds. Copeland and McDonald (1995) described the most common form of dormancy as primary dormancy and that it takes two forms: exogenous and endogenous dormancy.

Exogenous dormancy

Exogenous dormancy is generally related to physical properties of the seed coat, and is a condition in which the essential germination components (e.g. water, light, and temperature) are not available and prevent the seed from germinating. This form of dormancy is, therefore, under exogenous control. There are three factors responsible for exogenous dormancy: water, gases, and mechanical restriction.

Water

Impermeability of seed coats to water is typical of many species and these seeds are known as hard seeds. Water impermeability can be caused by both genetic and environmental factors. These seeds will then favour a constant moisture content in the embryo and not take up water.

Gases

The impermeability of gases through the seed coat has been described as a mechanism of dormancy governed by the seed coat. In this case the dormant seeds are less permeable to oxygen, thus retarding the aerobic metabolism required for germination. This impermeability of gases appears to be the cause of dormancy in a lot of grasses.

Mechanical Restriction

This type of dormancy can be caused by a physical restraint of the seed coat on an enlarging embryo. Due to this physical restraint the thrust developed during imbibition and growth is inadequate to rupture the seed coat and permit germination.

Under natural conditions, exogenous dormancy is overcome by the freezing – thawing of the soil, ingestion by animals, micro-organism activity, forest fires, natural soil acidity, and other factors. All of these factors may affect the integrity of the seed coat in some way. By the mechanical or chemical removal of the seed coat this type of dormancy can be overcome. This process is called scarification. Grinding seeds with abrasives or sand or shaking them are mechanical techniques that are often used to scarify seed coats. Other mechanical scarification techniques includes heating, chilling, drastic temperature shifts, brief immersion in boiling water, piercing of the seed coat with a needle, or exposure to certain radio frequencies, which may alter seed coat integrity, permitting penetration of both water and gases. The duration of these treatments are, however, critical, since prolonged treatment may cause damage, while brief treatments may not be sufficient to break dormancy. Chemical scarification techniques, which is the treatment of seed with chemicals to cause degradation of the seed coat, can also be used. Chemicals such as sulphuric acid, sodium hypochlorite and hydrogen peroxide have been used to scarify seeds. Recent techniques also include the use of selective seed coat enzymes such as cellulase and pectinase to degrade seed coats (Brant *et al*. 1971). Organic solvents such as alcohol and acetone have also been used to dissolve and remove water – insoluble compounds in the seed coat that could retard water entry into the seed and prevent imbibition (Rolston 1978).

Endogenous Dormancy

Copeland and McDonald (1995) stated that endogenous dormancy is the most prevalent dormancy found in seeds and that it is due to the inherent properties of the seed. This form of dormancy is under endogenous control, and could be, for example, that the seed contains an excess amount of inhibitor that must be removed before germination can occur. The duration of endogenous dormancy can be influenced by several environmental factors such as day length, moisture status, position of the seed in the inflorescence, age of the mother plant, and the temperature during seed maturation.

Gutterman (1993) found that plants differ in their response to photoperiod and their expression of seed dormancy. He used the example of, longer days that promote germination of *Polypogon monspeliensis, Carrichtera annua*, and *Cucumis prophetarum* seeds, and then short days, which enhance the germination in *Chenopoduim album, Portulaca oleracea*, and *Lycopersicon esculentum* (Gutterman 1982). The reason for the day-length effect on seed dormancy, however, is still not known.

The degree of endogenous seed dormancy can also be influenced by the moisture status of the mother plant or developing seed. Aspinall (1965) found that water deficits increase barley seed dormancy when they occur close to flowering but decrease dormancy when they occur at the final stages of seed maturation. Simpson (1990) also found that water stress during seed maturation reduced the level of dormancy in *Avena fatua*.

The position of the seed on the mother plant also influences endogenous dormancy. These effects are primarily attributed to differences in seed maturation, which are often expressed in seed weight. This can be shown by the example of seed from the *Apiacceae* family where the heavier, more mature seed are more dormant than seed produced elsewhere on the plant (Thomas *et al*. 1979). The dormancy of the seed can also be influenced by the age of the mother plant at the time of flower induction. Kigel *et al*. (1979) found that dormancy of seeds from *Amaranthus retroflexus* increased as the age of the plant increased.

Temperature during seed maturation is also known to influence the expression of dormancy. Datta *et al.* (1972) stated that higher temperatures produce less dormant seeds, and used the example of *Aegilops ovata,* which produced more germinable seed when exposed to 28/22ºC than to15/10ºC. Endogenous dormancy can, therefore, only be lifted by physiological changes such as rudimentary embryo maturation, response to growth regulators, changes in temperature, exposure to light, and endogenous rhythms, and not a physical alteration of the seed coat as in exogenous dormancy (Copeland & McDonald 1995).

Rudimentary embryo dormancy

Copeland and McDonald (1995) stated that seed of some species are shed before they are morphologically mature. These immature embryos are unable to germinate and are thus dormant. Further embryo maturation can occur following seed dispersal and may take a few days or several months. The changes that occur in these dry, dormant seeds, after dispersal is known as after-ripening.

Physiological dormancy

Copeland and McDonald (1995) described this form of dormancy as a result of the presence of growth inhibitors, the absence of growth promoters, or a combination of both. The levels of these compounds can be controlled by certain environmental stimuli such as light and temperature. A number of compounds have been identified as suppressing germination in seeds through metabolic inhibition. These compounds inhibit specific metabolic pathways. Examples of these compounds are: cyanide, phenolic compounds, coumarin and dormin. Many substances possessing high osmotic pressures can also inhibit germination of seed through a process called osmotic inhibition. Compounds such as sugars or salts in sufficient concentrations may compete so successfully for water that the seed never becomes fully imbided and thus remains ungerminated.

Physiological dormancy can be overcome by various methods. Seeds that are dormant due to osmotic inhibition can be germinated after removing the seed from the influence of the inhibitor, or by a process called leaching where the seed is placed in water to remove or dilute the inhibitor. Seeds that possess metabolic inhibitors located in the seed coat can germinate after removal of the seed coat by mechanical or chemical scarification.

A number of seeds have been found to possess more than one of the dormancy mechanisms, and the different types of dormancy are thus by no means mutually exclusive (Bradbeer 1988). McDonald and Khan (1977) found Indian rice grass *(Oryzopsis hymenoides*) seeds to posses both seed coat (exogenous) and physiological (endogenous) dormancy. A combination of treatments may, therefore, be necessary in some cases to overcome dormancy.

Conclusion

The growing importance of planted pastures in a country with limited natural resources such as South Africa has already been emphasized. But to achieve the goal of addressing this problem careful planning by producers will be necessary. Annual subtropical grasses, such as *U. brachyura* can play an important role in addressing some of these problems. Research such as in this project, is therefore, very important for finding solutions for problems that might arise when developing new and better crops, to meet specific requirements in animal production systems and rehabilitation practices.

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Chapter 2

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

The effect of different drying temperatures on the viability and germination of *Urochloa brachyura* (Hack.) Stapf seed

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Urochloa brachyura is an annual tropical grass collected in Gauteng Province, selected for its high yield and quality. Seed harvested from this crop in the summer of 1999/2000 generally had a poor germination. This prompted an investigation into possible causes for poor germination and ways of improving seed quality. The objective of the study was to determine whether different drying temperatures would have an influence on the quality of the seed. The seed evaluated in this trial was harvested with a brush harvester in the summer of 2001/2002 and seed samples from three different harvests were dried to a water content of approximately 10% at 5, 20, 30, and 45°C. The germination performance was evaluated using the standard germination test procedure for *U. mosambicences* and viability was determined using the Tetrazolium (TZ) test procedure. There were no significant differences between the treatments in terms of germination performance, which once again were low (<4%). There were also no significant differences in the viability, as determined with the TZ test, between the samples dried at 20, 30, or 45°C. The seeds dried at 5°C, however, had a lower percentage of seeds with abnormal staining and a higher percentage of dead seeds. It is, therefore, concluded that drying temperatures between 20°C and 45°C will not have an effect on the quality of *U. brachyura* seed.

Keywords: annual tropical grass, dormancy, seed quality, tetrazolium test.

Introduction

Urochloa brachyura as described by Gibbs Russle *et al.* (1990) is a tufted annual tropical grass native to South Africa. It grows 200 – 1200mm high, and flowers from October to April. It is closely related to the perennial grass *U. oligotricha. U. brachyura* was selected for its high yield and quality (Pieterse 1999), and is adapted to Savanna, Grassland and Nama-Karoo biomes. This species has possible application in rehabilitation, as well as in animal production systems, because of its fast low growing habit, high yield and quality. Because it is an annual, it may also have potential for use in rotational cropping, where it can produce high quality forage over a short period of time. Although a large amount of seed is produced by *U. brachyura* the germination percentage is poor. Ways of improving viability and germination are, therefore, being evaluated. Seed harvested from this crop in the summer of 1999/2000, although having a viability of 54%, had a poor germination performance (<4%). This prompted an investigation into possible causes for the poor germination. The objective of the study was to determine whether different drying temperatures would have an influence on the quality of the seed.

According to literature high temperatures during the drying process of seed can have a negative influence on seed quality. Loch *et al.* (1999) also implied that using lower temperatures during the drying process could allow for prolonged development of immature seed. Newly harvested seed of all tropical grasses is quite moist. Freshly harvested grass seed can have a moisture content of 40 – 70 percent. Such seed will deteriorate rapidly if it is not dried sufficiently before it is stored. According to Tainton (2000) freshly harvested seed stored in sacks or bins may heat sufficiently to cause it permanent damage within as little as one hour. The seed must, therefore, be dried to a safe moisture content (8 –12 %) to prevent loss of germination capability during storage. Humphreys and Riveros (1986) stated that it is expected that seed will ferment at 18 to 20 percent water content, grow moulds at 12 to 14 percent, but that at 8 to 9 percent insect activity will cease.

There is a relationship between safe drying temperature and initial seed moisture content. Seed viability is generally decreased by drying at temperatures above 40°C. The general recommendation for field crops is to dry the seed at temperatures of no more than 32, 37 and 43°C for moisture contents of more than 18 percent, 10 to 18 percent, and less than 10 percent moisture, respectively (Herbage Seed Unit 1994). Generally, there are three main methods of drying seed in sub-Saharan Africa. These are sundrying, natural forced airdrying and artificial drying. In humid environments, artificial drying equipment, that is not dependent on the weather, is essential and will provide better control of seed quality. Artificial drying procedures, when improperly applied could, however, also produce seed lots that lose viability in storage with unusual speed (Harrington 1972). Due to South Africa's hot and dry climate, seed can generally be effectively dried without expensive artificial dryers and the latter would, therefore, not generally be economically viable.

The proportion of seeds that will germinate to form healthy plants defines seed quality, and the three basic parameters for seed quality are viability, vigour and seed purity (Bradbeer 1988). A viable seed is one that is capable of germinating under suitable conditions. Assessing seed viability is thus an excellent tool in predicting potential seed germination. Tetrazolium testing has been developed to furnish quick estimates of seed viability. This test distinguishes between viable and dead tissues of the embryo on the basis of their relative respiration rate in the hydrated state. A germination test is an analytical procedure to evaluate seed viability and germination under standardized conditions, and is probably the most convincing and acceptable index of seed quality. By performing these two tests on a seed lot valuable information on the quality, and causes of seed deterioration, can be obtained. Due to the poor germination performance of *U. brachyura* seed harvested in the 1999/2000 season, when the drying temperature was approximately 40°C, it is believed that this drying procedure could have affected the viability of the seed resulting in the poor germination performance.

The hypothesis is, therefore, that different drying procedures will have an effect on the viability and germination performance of *U. brachyura* seed.

Material and Methods

Experimental seed

In the summer of 2001/2002 a pure stand of *U. brachyura* was established on the Hatfield Experimental Farm of the University of Pretoria. The farm is situated 1353m above sea level, at 25° 45' South and 28° 16' East, in a summer rainfall area with a long term mean annual precipitation of 708 mm. The soil form is Hutton (MacVicar *et al.* 1997) with a weak structure and a homogenous red colour and is non-calciferous. The soil can be described as a sand-clay-loam with a 20 - 35% clay content. The two blocks used were each 0.0435 ha in size. Given the low germination performance of the seed a very high seeding rate was used. Each block received 100kg N/ha after germination and supplemental irrigation was also applied. The seed was harvested using a brush-harvester. Three harvests were taken from these blocks at different dates, and seed samples from each harvest were taken and used in the drying experiment.

Drying procedure

The initial water content of the seed from each harvest was calculated. This was done by drying a seed sample of each harvest at 100°C, and expressing the water content of the seed as a percentage of the dry matter. For the application of the four temperature treatments seed were dried in three different ovens. The temperatures used were 5, 20, 30, and 45°C. For the 5°C treatment seed were placed in a cold room. The seed was then dried to a moisture content of approximately 10 percent. After drying the seed samples were marked and stored in a cold room at 5°C.

Tetrazolium test procedure

The tetrazolium tests were carried out on all samples strictly according to the principles and procedures stipulated by the International Seed Testing Association (ISTA 1985). A germination chamber at the Experimental Farm of the University of Pretoria was used to carry out these tests. Three replicates of 50 seeds each were used. During preconditioning, seed were hydrated by placing them between a wet medium (germination paper) for 16 – 24 hours at 20°C. Germination paper was used. A longitudinal bisection through the embryo was then done on each seed in order to facilitate entry of the tetrazolium solution into the embryo. The tetrazolium derivate used for the staining procedure was 2,3,5-triphenyl tetrazolium chloride (TCC). To prepare the 0.1% solution, 1gram of tetrazolium powder was dissolved in 1000ml distilled water. The hydrated seeds were then placed in petri dishes containing the TZ – solution for 18 hours at 30°C. After staining the TZ – solution was removed with a medicine dropper, and the seeds were evaluated under a stereoscopic microscope. In this evaluation the seeds were divided into the following groups according to the red staining pattern:

Normal – Seed containing a clearly defined, uniformly stained embryo;
Abnormal – Seed with an unstained upper or lower part of the embryo, or a very pale pink stain, or
Dead – Seed that show no staining of the embryo (ISTA 1985).

Germination test procedure

The standard germination test procedure for *U. mosambicences,* a perennial species, was used as prescribed by ISTA (1985). Four replicates of 100 seeds each were used. Seeds were placed in petri-dishes. Each petri-dish was lined with germination paper, and the seeds were placed on top of the germination paper. 10 ml KNO_3 (0.2% solution) was added to each petri-dish to wet the germination paper. The petri-dishes were then placed in a germination chamber for 16 hours at 30°C, and 8 hours at 20°C respectively for 21 days.

The first evaluation was done after seven days, when the seeds that had germinated (emergence of radicle) were counted and removed. The final evaluation (count) was done after 21 days.

Statistical analysis

An analysis of variance with the ANOVA model (Statistical Analysis Systems, 2001) was used to determine the significance between different treatments. Means and standard deviations (SD) were calculated. Significance of difference (5%) between means was determined by multiple comparisons using Tukey t-test (Samuels 1989).

Results and Discussions

Tetrazolium test

The TZ – test results for the three different harvests were analyzed separately. Similar results for each harvest were obtained. The viability tests showed that there were no significant differences among the 20, 30, and 45°C treatments, but that seed dried at 5°C had a higher percentage of dead seed and a lower percentage of seed showing abnormal staining. Data from the second harvest is presented in Table 1. to illustrate these effects.

Table 1. Tetrazolium – test data of the second seed harvest as influenced by drying temperature.

	Average number of seeds per treatment		
Treatment	**Normal**	**Abnormal**	**Dead**
5 °C	13.00 ^{a}	18.33 ^{n}	18.67 ^{p}
20°C	15.00 ^{a}	27.33 ^{m}	7.67 ^{q}

30°C	12.33 [a]	30.67 [m]	6.67 [q]
45°C	11.67 [a]	30.67 [m]	7.67 [q]
L.S.D (P < 0.05)	11.701	7.313	7.160

Values in columns with the same superscript do not differ significantly. Significant differences were determined using the Tuckey's Studentized Range Test.

In Figure 1., the Tetrazolium-test data of all three harvests were averaged and expressed in a histogram. It is clear that the drying temperatures between 20 and 45°C did not negatively affect the viability of the seed, but that the quality of seeds dried at 5°C was much lower.

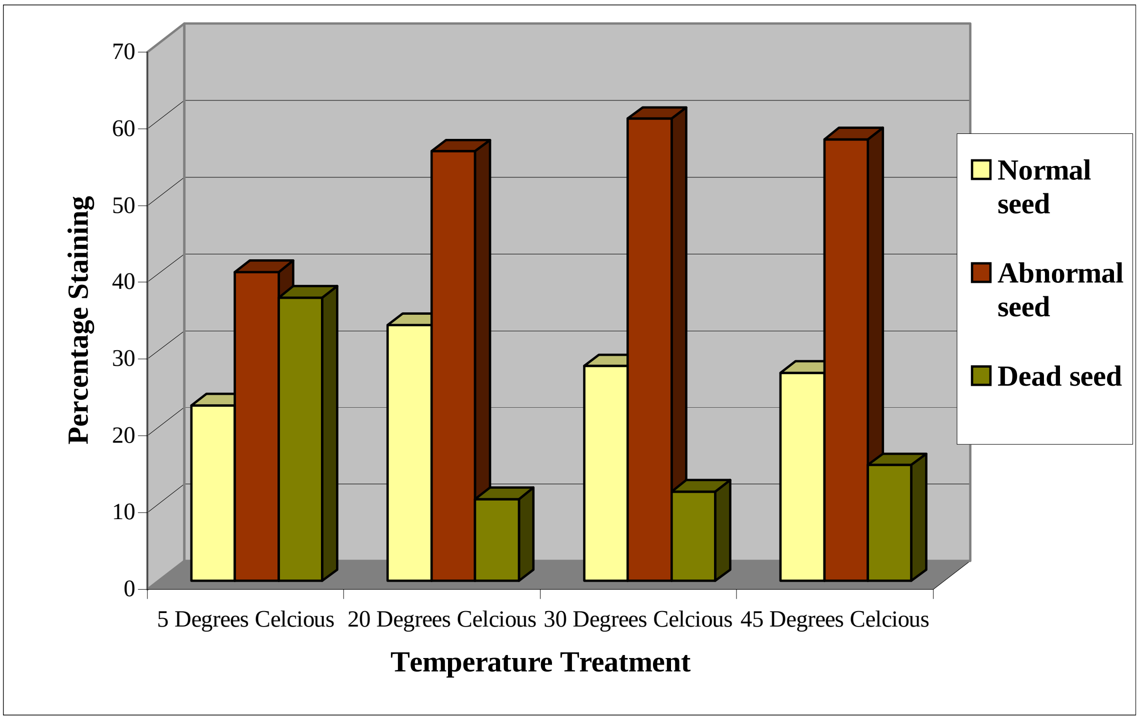

Figure 1. Tetrazolium-test results of three different harvests, showing the average percentage of normal, abnormal and dead seeds.

Germination test

Similar test results were also obtained from the germination tests conducted on the three different seed harvests. Improving the drying and storage conditions did not result in any improvement in germination. The germination remained very poor and data could not be analyzed, as very little or no seed germinated. A closer examination of the ungerminated seed, revealed that normal root development was replaced by a mass of fibrous root growth. Seed was, therefore, not dead but germination had been inhibited in some way.

Conclusion

According to the Tetrazolium-tests, seed quality of *U. brachyura* has not been affected by drying temperatures between 20 and 45°C. It is, therefore, evident that the 40°C drying temperature used in the earlier experiment could not have damaged the seed, and could not be held responsible for the poor germination performance of the seed. A closer examination of the seed that did not germinate, revealed that normal seedling growth had been replaced by a mass of fibrous root growth. This confirmed that poor germination performance could not be attributed to lack of viability, but was rather a form of post harvest dormancy.

It can, therefore, be concluded that *U. brachyura* seed should be dried using temperatures ranging between 20 and 45°C, and that temperatures of 5°C or lower will have a negative influence on seed quality.

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Chapter 3

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The evaluation of different dormancy breaking procedures to improve germination of *Urochloa brachyura* (Hack.) Stapf*.*

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Urochloa brachyura is an annual tropical grass collected in Gauteng Province, selected for its high yield and quality. Seed harvested from this crop in the summer of 1999/2000 generally had a poor germination. Tetrazolium-tests done on these seedlots showed a viability of 54%, and it was concluded that some form of post-harvest dormancy existed. This prompted an investigation into possible causes for the poor germination and the evaluation of different dormancy breaking procedures. The objective of the study was to improve germination by applying the most effective dormancy breaking procedures. The use of gibberrillic acid (Ga_3), potassium nitrate (KNO_3), scarification, leaching, cold stratification, and heat treatments were evaluated for breaking this dormancy. Only the heat treatments had any effect on the germination. The germination results suggest that the 45°C temperature treatment for three weeks may increase the germination performance of *U. brachyura* to between 30 and 40%. Applying the temperature treatment for less than three weeks also depressed germination.

Keywords: dormancy, germination, temperature treatment, viability.

Introduction

U. brachyura, as described by Gibbs Russle *et al.* (1990), is a tufted annual tropical grass native to South Africa. It grows 200-1200mm high, and flowers from October to April. It is closely related to the perennial grass *U. oligotricha. U. brachyura* was selected for its high yield and quality (Pieterse 1999), and is adapted to Savanna, Grassland and Nama-Karoo biomes. This species has possible application in rehabilitation as well as in animal production systems because of its fast low growing habit, high yield and quality (Pieterse 1999). Because it is an annual, it may also have potential for use in rotational cropping where it can produce high quality forage over a short period of time. Although a large amount of seed is produced by *U. brachyura* the germination percentage is poor. Seed harvested from this crop in the summer of 1999/2000 had a germination percentage of less than 4%. Tetrazolium-tests done on these seedlots showed a viability of 54%, and it was concluded that germination are inhibited by some form of post-harvest dormancy. Methods of improving germination were, therefore, evaluated in this investigation. The objective of the study was to improve germination by identifying the most effective dormancy breaking procedures.

Some seeds are capable of germinating only days after fertilization. Others may be dormant and may require an extended rest period or additional development before germination can occur. According to Partridge (1996) *Panicum maximum* seed can remain dormant for up to nine months, and *Chloris gayana* seed for about three months. He also stated that *Brachiaria decumbens* has a type of seed coat- induced dormancy, which lasts virtually throughout the storage life of the seed. Dormancy, however, can be overcome and is only a natural safety mechanism to ensure survival. Copeland and McDonald (1995) described true dormancy as a state in which seeds are prevented from germinating even under environmental conditions normally favourable for germination.

Germination may be inhibited in seeds for a number of reasons: (1) rudimentary embryos, (2) physiologically inactive embryos (inactive enzyme systems), (3) mechanically resistant seed coats, (4) impermeable seed coats, and (5) presence of chemical inhibitors (Amen 1968). Any of these factors could be a cause of germination delay in *U. brachyura*. Akamine (1944) attributed the germination delay in *U. pullulans* to two factors namely embryo dormancy, and physical constriction of the embryo by the palea and lemma. Exogenous dormancy is generally related to physical properties of the seed coat, which limits the availability of essential germination components (e.g. water, light, and temperature). Under natural conditions, exogenous dormancy is overcome by the freezing/thawing of the soil, ingestion by animals, micro-organism activity, forest fires, natural soil acidity, and other factors. This type of dormancy can also be overcome by a process called scarification, which is the chemical, or mechanical, removal of the seed coat (Copeland and McDonald 1995).

With endogenous dormancy germination is inhibited due to the inherent properties of the seed. This form of dormancy is under endogenous control, and could be for example that the seed contains an excess amount of inhibitor that must be removed before germination can occur. Endogenous dormancy can be lifted by physiological changes such as rudimentary embryo maturation, response to growth regulators, changes in temperature, exposure to light, and endogenous rhythms, but not by a physical alteration of the seed coat as in exogenous dormancy (Copeland and McDonald 1995).

Seed of some species are shed before they are morphologically mature, and further embryo maturation might be needed before they can germinate. This is called rudimentary embryo dormancy, and the changes that occur in these dry dormant seeds, after dispersal, are known as after-ripening.

Physiological dormancy is a result of the presence of growth inhibitors, the absence of growth promoters, or a combination of both. This type of dormancy can be lifted by a process called leaching, or by scarification. Leaching typically requires exposing the seeds to an excess of water that dilutes or removes the inhibitor from the seed. Bradbeer (1988) stated that a number of seeds have been found to possess more than one dormancy mechanism. McDonald and Khan (1977) found that Indian rice grass

(*Oryzopsis hymenoides*) seeds possessed both seed coat (exogenous) and physiological (endogenous) dormancy.
A combination of treatments may, therefore, be necessary in some cases to overcome dormancy.

Material and Methods

Experimental seed production.

In the summer of 2001/2002 a pure stand of *U. brachyura* was established on the Hatfield Experimental Farm of the University of Pretoria. The farm is situated 1353m above sea level, at 25° 45' South and 28° 16' East, in a summer rainfall area with a long term mean annual precipitation of 708 mm. The soil form is Hutton a (MacVicar *et al.* 1977) with a weak structure and a homogenous red colour and is non-calciferous. The soil can be described as a sand-clay-loam with a 20 - 35% clay content. The two blocks used were each 0.0435 ha in size. Given the low germination performance of the seed a very high seeding rate was used (+- 60kg/ha). Each block received 100kg N/ha in the form of limestone ammonium nitrate (28%N) after germination and supplemental irrigation was also applied to ensure that there was no moisture stress. The seed was harvested using a brush-harvester. Three harvests were taken from these blocks. The first harvest was taken when 50% of inflorescences started to shed seed, with subsequent harvests at three week intervals thereafter.

All experimental procedures used to break dormancy, were carried out using the same batch of seed. The following trials were conducted:

Gibberrillic acid (Ga_3) and Potassium Nitrate (KNO_3)

The use of the naturally occurring plant growth regulator gibberrillic acid (Ga_3), and potassium nitrate (KNO_3), which are commonly used to improve germination performance, were evaluated in this experiment. Germination tests were carried out according to the standard germination test procedure prescribed by the International Seed Testing Association (ISTA 1985). 100 seeds were placed in each petri-dish. For these two treatments Ga_3 and KNO_3 (0.2% solution) were used instead of the distilled water, which is normally used in germination tests. Four replicates for each treatment were used, with distilled water being used in the control treatment. 7.5ml of each chemical were added to each petri-dish. Germination was done at alternating temperatures of 30/20°C for a 16/8-hour cycle. The final evaluation was made after 21 days.

Scarification (removal of palea and lemma)

The mechanical restriction imposed on the germinating embryo by the palea and lemma, can be eliminated by the physical, or chemical, removal of the palea and lemma. The most effective physical removal procedure for *U. brachyura* seed was by applying friction on the seed coat. Rubbing a few seeds between the thumb and index finger achieved this. Normal germination tests, as prescribed by ISTA (1985), were then carried out on these seeds and control seeds to evaluate the effectiveness of physical scarification. Four replications per treatment were used.

Leaching

In an attempt to leach possible germination inhibitors, seeds were placed in distilled water for 36 hours. The water was replaced with fresh distilled water every 12 hours. After 36 hours a standard germination test, as prescribed by ISTA (1985), was carried out to evaluate the effectiveness of the leaching procedure. The control treatment was not subjected to the leaching procedure. Four replicates per treatment were used.

Cold Stratification

Cold stratification, or prechilling, was also carried out on *U. brachyura* seed in an attempt to improve the germination percentage. The seeds were subjected to 5°C for 7 days prior to the standard germination test. The petri dishes with seed were prepared as prescribed by ISTA (1985), and placed in a cold room at 5°C for 7 days. After 7 days the petri dishes were taken out and placed in a germination chamber for the standard germination test. Four replicates per treatment, and a completely randomised design were used. The control did not receive a prechilling treatment prior to the germination test. Alternating temperatures of 30/20°C for a 16/8-hour cycle were used, and the final evaluation was done after 21 days.

Heat treatment

Six heat treatments were evaluated for shortening the after-ripening period needed for germination to occur. The temperatures of three drying ovens were set to 45, 60, and 70°C respectively. Air-dry *U. brachyura* seeds, with a post harvest age of 12 months, were subjected to the above-mentioned temperatures for three or six weeks. After the temperature treatments, germination performance was evaluated using the standard germination test procedure as prescribed by ISTA (1985). Four replicates for each treatment were used. The control treatment did not receive any heat treatment. Treatments were applied using a completely randomised design. The experiment was repeated using shorter treatment periods in order to make the treatment process more viable. In this trial seeds were subjected to a temperature treatment of 45°C for 7,14, and 21 days, after which, effectiveness was recorded by performing germination tests. The control treatment did not receive any temperature treatment. Four replicates for each treatment were used.

Statistical analysis

An analysis of variance using the GLM model (Statistical Analysis Systems 2001) was conducted to determine the significance between different treatments and levels and the interaction between treatments and levels. Means and standard deviations (SD) were calculated. Significance of difference (5%) between means was determined by multiple comparisons using Tukey t-test and the Bonferoni test (Samuels 1998).

Results and Discussions

Gibberrillic acid (Ga_3) and Potassium Nitrate (KNO_3)

A statistical analysis could not be performed on the data because of the poor germination, and the fact that the data were not normally distributed.
No marked benefits were obtained by treating with either gibberrillic acid or potassium nitrate. Germination rates were low (<4%) and Ga_3 and KNO_3 were not, therefore, effective in improving the germination performance of *U. brachyura.*

Scarification

The mechanical removal of the palea and lemma, which, would not be a commercially viable procedure because of high manpower inputs, also did not have a marked impact on germination. The germination percentage was increased from <4%, on the control, to 6% which is, however, still very low.

The data could not be analysed statistically as it were not distributed normally due to the low germination. In spite of this fact it is clear that the removal of palea and lemma could not be a viable procedure for improving germination performance in *U. brachyura,* because of high labour requirements.

Leaching

Due to low germination rates, the data was not distributed normally, and could not be analysed statistically. It was, however, clear that the leaching procedure did not have any influence on the germination performance of *U. brachyura* seed.

Cold Stratification

Due to low germination rates, these data also could not be analysed statistically, although, it was clear that cold stratification also had no influence on the germination of *U. brachyura*.

Heat treatment

Seeds from the control treatment failed to germinate and were, therefore, not included in the statistical analysis. The rest of the data for the heat treatments were analysed to determine which treatments were the most effective (Table 1.).

The germination results from this aspect of the investigation suggest that the 45°C temperature treatment applied for 3 weeks may increase the germination of *U. brachyura* to between 30 and 40%. The germination results of the 45°C treatment were significantly better than the 60 and 70°C treatments (Table 1.). Temperatures higher than 45°C were not as effective, although considerably better than the control. The germination also declined where the temperature treatments exceeded 21 days. Treatment periods should, therefore, not exceed 21 days.

Table 1. The influence of three different temperature treatments on the germination of *U. brachyura* seed.

	Germination Percentage		
Treatment Period	**Temperature treatments (°C)**		
	45°C	**60°C**	**70°C**
21 days	34	22	21
	28	20	16
	32	25	15
	30	24	20
Mean	**31[a]**	**22.75[b]**	**18[b]**
42 days	19	15	12
	16	13	7
	24	10	9
	20	11	10
Mean	**19.75[b]**	**12.25[c]**	**9.5[c]**

Values in columns with the same superscript do not differ significantly. Significance of difference (5%) between means was determined by using Bonferoni's test (Samuels 1989). Control treatments failed to germination and were not included in statistical analysis.

The evaluation of shorter treatment periods (<21days), indicated that when applying the temperature treatment of 45°C for less than 21days, the germination declined (figure 1.). The statistical analysis confirmed that the germination results for the 45°C treatment (21 days), were significantly better than all other treatments. The optimum temperature treatment period is, therefore, 21 days.

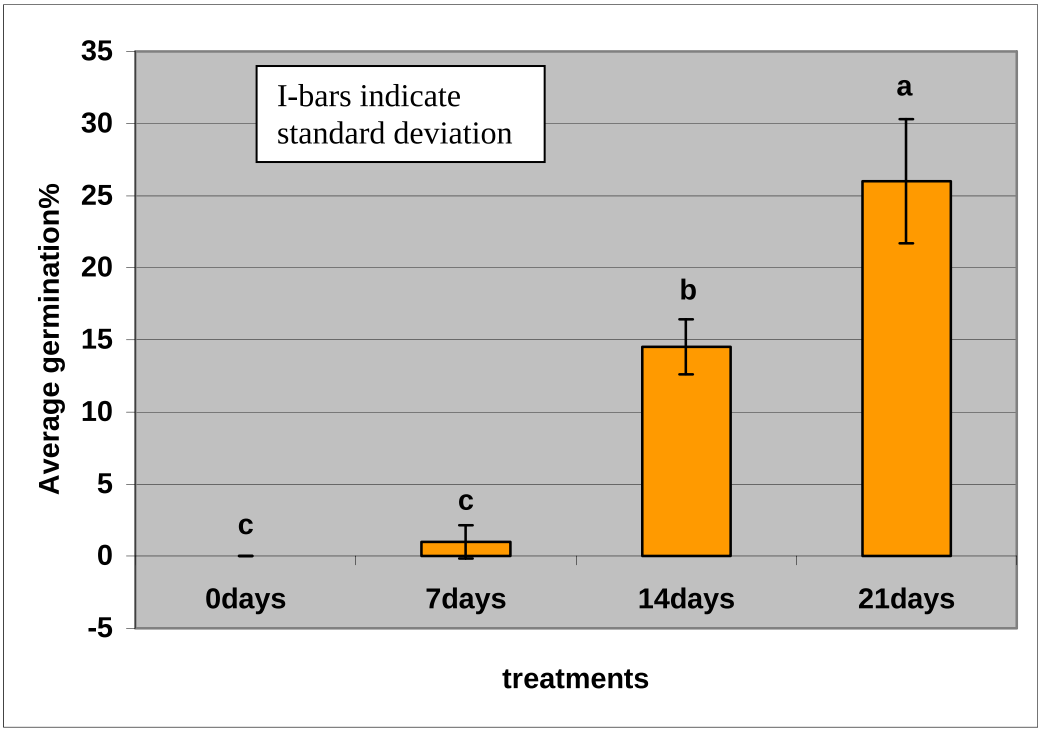

Figure 1. The influence of a temperature treatment for 0, 7, 14, and 21 days at 45°C on the germination percentage of U*. brachyura* seed. Different letter data labels, indicate significant differences.

Conclusions

The use of gibberrillic acid (Ga_3), potassium nitrate (KNO_3), scarification, leaching, and cold stratification, were not effective in improving the germination of *U. brachyura*. Results with heat treatments did, however, indicate that the germination could be improved by applying specific temperature treatments. The heat treatment was the only treatment tested that improved germination. From these results it is evident that a treatment of 45°C for three weeks is the most effective. This treatment may improve the germination of *U. brachyura* seed to between 30 and 40% compared to <4% or 0% for the control.

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Chapter 4

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

The influence of depth of sowing on the emergence of *Urochloa brachyura* (Hack.) Stapf.

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Urochloa brachyura is an annual tropical grass collected in Gauteng Province and selected for yield and quality. Seed harvested in the summer of 1999/2000 generally had a poor germination performance. It was found that when applying a 45°C treatment for 3 weeks to seed with a post-harvest age of 12 months, the germination performance was significantly improved to 30%. Other ways of further improving germination of seed, receiving this temperature treatment, have now been evaluated. In this investigation seeds were sown at five different depths (0mm, 5mm, 10mm, 20mm, 30mm). The objective of the study was to determine the optimum depth of sowing for *U. brachyura.* It was found that the emergence of seedlings, where seed was covered with soil, was significantly better than the control, which was not covered. The highest emergence was found when seeds were planted at a depth of 30mm. By using this optimum depth of sowing the emergence of *U. brachyura* was increased to between 40-50%.

Additional index words: depth of sowing, emergence, germination.

Introduction

Urochloa brachyura is a tufted annual tropical grass, native to South Africa. It is described by Gibbs Russle *et al.* (1990) as an annual growing 200-1200mm high, which flowers from October to April. *U. brachyura* was selected for its high yield and quality characteristics in the Gauteng region (Pieterse 1999), and is adapted to Savanna, Grassland and Nama-Karoo biomes. It produces an abundance of leafy material and has a fast low growing habit, which makes it suitable for use in animal production systems as well as in rehabilitation practices. Because it is an annual, it may also have potential for use in rotational practices where it can produce high quality forage over a short period of time.

One of the most common causes of failure with the establishment of small-seeded species is the sowing depth. Maximum sowing depth is constrained by endosperm reserves, which must be adequate to support hypocotyl or epicotyl elongation until seedlings emerge above the soil and begin photosynthesising, as well as by soil type and condition. The elongation rate is a function of genotype, temperature and soil water (Herbage Seed Unit 1994). Tainton (2000) also stated that seeding depth is usually a compromise between two factors:

(a) The capacity of food reserves contained in the seed to support seedling growth (the larger the seed the larger the reserves)

(b) The better anchorage, moisture supply and nutrition associated with an increasing depth of seed placement.

Care must, therefore, be taken not to plant too deep. Most pasture species should be planted into a firm seedbed to a depth of between 0.5 cm and 1.5 cm, although some species like *Digitaria eriantha* are sown directly onto the soil surface with good results (Tainton 2000). When seed is sown directly onto the soil surface the seedbed should preferably be rolled to increase contact between soil and seed. Sowing grass seed of some species 2-5 cm deep, however, allows them to reach stored soil moisture and to germinate ahead of weeds (Partridge 1996). The objective of this investigation was to determine the optimum sowing depth for *U. brachyura,* as determined by the emergence of seedlings.

Materials and Methods

Experimental seed

The seed used in this experiment had a post-harvest age of 12-months. A heat treatment of 45°C for three weeks, had been applied to the seed to improve germination. This treatment had been found, in a previous experiment (Roselt *et al.* 2005), to improve the germination of *U. brachyura*. All seed used had received the same treatment.

Germination experiment

Seeds were planted in three litre pots. These pots were filled with soil from a Hutton soil form of weak structure and a homogenous red colour (MacVicar *et al.* 1997). The soil can be described as a sand-clay-loam with a 20-35% clay content. The seeds were planted at five different depths, namely: 0mm, 5mm, 10mm, 20mm, and 30mm. The seed were sown on the soil surface, and then covered by the amount of soil needed to create the specific depth. The treatment where seed was sown onto the soil surface, but not covered (0mm), was used as the control. There were five treatments with four replicates and they were assigned to the pots according to a completely randomised statistical design. The 20 pots were placed in a germination chamber at alternating temperatures of 30/20°C for a 16/8-hour cycle. The pots were watered to field capacity before seeds were planted. The pots were also lined with plastic to prevent water from leaching out. After the seeds were planted the pots were watered daily to field capacity, to prevent the upper soil layer from drying out. This was done using a fine sprayer so as to not disturb the layer of soil covering the seed. All treatments received the same amount of water, as pots were kept at field capacity. The first germination count was at seven days, and the final evaluation was made after 21 days.

Statistical Analysis

An analysis of variance with the ANOVA model (Statistical Analysis Systems 2001) was used to determine the significance between different treatments. Means and standard deviations (SD) were calculated. Significance of difference (5%) between means was determined by multiple comparisons using the Tukey t-test (Samuels 1998).

Results and Discussions

Table 1. illustrates the rate at which seeds germinated. It is clear that although some treatments were planted deeper than others, there were no significant differences in terms of rate of emergence when evaluations were made after 7, 14, and 21 days. More than 95% of seeds that germinated did so within seven days after they were planted. Sowing up to a depth of 30mm, therefore, did not have a negative influence on the rate of emergence of seedlings.

Table 1. The rate of emergence of *U. brachyura* seedlings, sown at different depths.

Average percentage of seedling emergence

	Depth of sowing				
Days	**0mm**	**5mm**	**10mm**	**20mm**	**30mm**
After					
7 days	6^{a}	33.25^{b}	32^{b}	33.75^{b}	40.75^{b}
14days	6.75^{a}	33.75^{b}	32.5^{b}	34.50^{b}	41^{b}
21days	6.75^{a}	33.75^{b}	32.5^{b}	34.50^{b}	41^{b}

Values in columns with the same superscript do not differ significantly. Significance of difference (5%) between means was determined by multiple comparisons using Tukey t-test (Samuels 1989).

The emergence data presented in figure 1. indicates significant differences in emergence between the control (0mm) and treatments with different seeding depths. From the first emergence count made after seven days, it was evident that the seed covered with soil germinated much better than the control, which was not covered.

A histogram of the average emergence percentages of the 5 treatments (figure 1.) indicates a difference of at least 25.75% between seeds which were covered and those, which were not covered.

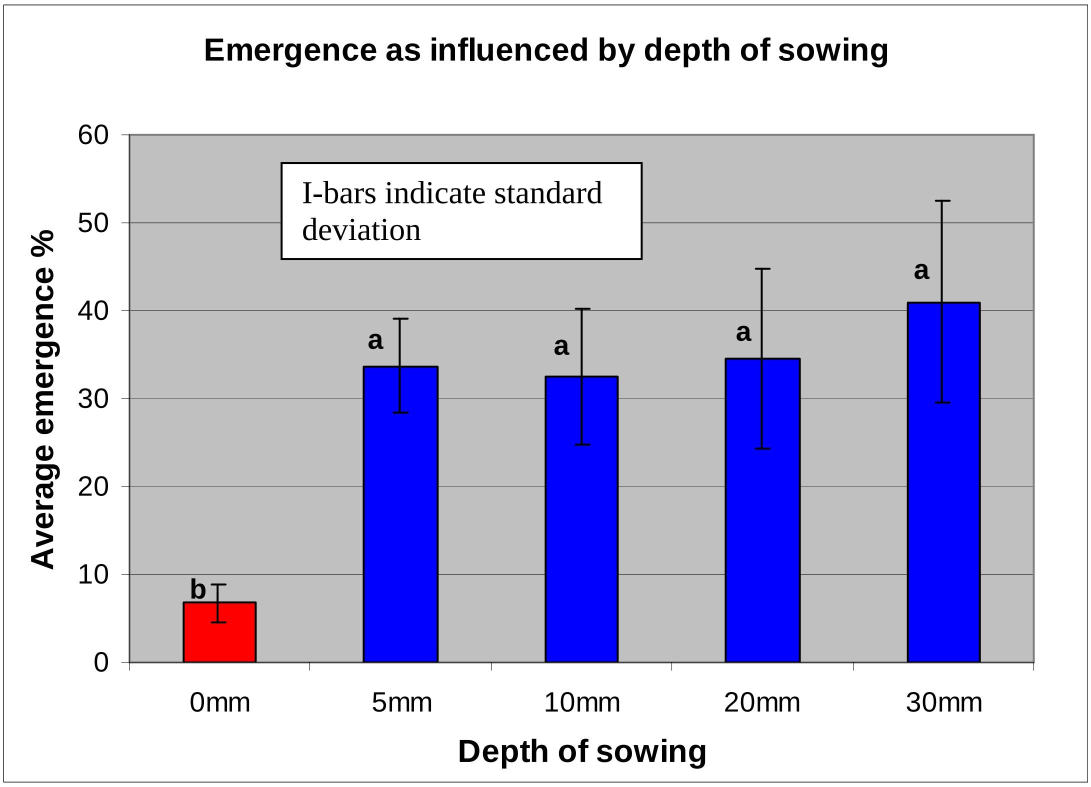

Figure 1. The average seedling emergence of *U. brachyura* seed, as influenced by depth of sowing. Different letter, data labels, indicates significant differences.

Conclusion

The emergence results obtained in this experiment indicates that although the 30mm deep treatment gave the best result, there were not significant differences between the 5, 10, 20 and 30mm sowing depths, and that sowing seed of *U. brachyura* on the soil surface resulted in the lowest emergence. Under these conditions the optimum depth of sowing for *U. brachyura*, therefore, appear to be at least 5mm with the highest emergence being recorded with 30mm of soil coverage. Such planting depths resulted in seedling emergence of up to 50%, as was the case in some replications of this experiment.

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Chapter 5.

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

The influence of water stress on the yield and seed production of *U. brachyura* (Hack.) Stapf.

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Urochloa brachyura is an annual tropical grass, collected in Gauteng Province, which was selected for its high yield and quality. The unpredictable annual rainfall in South Africa calls for selecting and developing plants which are adapted to these extreme conditions and which will be important for sustainable production systems. Water deficits, in general, result in a decline in dry matter production (Turner & Begg 1978). The objective of this investigation was to determine the influence of water stress on the dry matter production and seed production of *U. brachyura.* The study was conducted as a pot trial under glasshouse conditions. The plants were watered regularly to 75%(control), 50%(treatment 1) and 25%(treatment 2) of field capacity. Data collected included dry matter production and seed production. Results indicate that when the amount of water applied decreased from 75% of field capacity to 50% of field capacity, a decrease in dry matter production of 53% was experienced. When even less water was applied (25% of field capacity), dry matter production did not decline further. The difference in seed production between the control treatment and treatment 1 was 52% while seed production of treatment 2 was a further 48% lower than that of treatment 1. Water deficits have a definite negative influence on the dry matter production and the seed production of *U. brachyura* and can thus have a

strong negative impact on the successful re-establishment of this annual species in water stressed environments.

Keywords: dry matter production, seed production, water deficits.

Introduction

South Africa has limited natural resources. The single most limiting factor in agriculture is, in general, the low and unpredictable annual rainfall. Approximately 65% of the country is arid or semi-arid, with only 28% of the country receiving more than 600 mm of rainfall per annum (Palmer & Ainslie 2002). The selection and development of plant species adapted to these extreme conditions is, therefore, very important for sustainable production in South Africa. Dannhauser (1985) stated the importance of genetic adaptability of different species to arid conditions, and uses the example of *Anthephora pubescens* and *Cenchrus ciliaris* that can be established in low rainfall areas.

Urochloa brachyura as described by Gibbs Russle *et al.* (1990) is a tufted annual tropical grass native to South Africa. It grows 200 – 1200mm high, and flowers from October to April. It is closely related to the perennial grass *U. oligotricha*. *U. brachyura* was selected for its high yield potential and quality (Pieterse 1999), and is adapted to Savanna, Grassland and Nama-Karoo biomes (Gibbs Russle *et al.* 1990). This species has possible application in rehabilitation as well as in animal production systems because of its fast low growing habit, high yield and quality. Because it is an annual, it may also have potential for use in rotational cropping where it can produce high quality forage over a short period of time.

Water deficits, in general, resulted in a decline in dry matter production (Turner & Begg 1978). The degree to which production is affected varies, and is a function of the intensity, duration, and stage at which the water deficits occur (Alcocer-Ruthling *et al.* 1989). Turner & Begg (1978) further stated that the lower production could be attributed to the reduction in leave size, and the increased rate at which older leaves die off. Sufficient plant available water, on a continuous basis, is necessary for optimal production of a grass plant. Some plants can undergo physiological and morphological adaptations in order to maintain a relatively high production efficiency, while experiencing stress conditions (Hull *et al,* 1978; Steynberg 1992).

The objective of this investigation was to determine the influence of water stress on dry matter production and seed production of *U. brachyura.*

Materials and Methods

The experiment was conducted as a pot trial under glasshouse conditions. The pots were each filled with 12kg air-dried soil. Each pot was lined with plastic to prevent leaching. The soil used was a Hutton soil form of weak structure and a homogenous red colour (MacVicar *et al.* 1997). The soil can be described as a sand-clay-loam with a 20-35% clay content. For the application of the treatments the water holding capacity of the soil was determined by determining the difference between the wet and dry mass of the soil, and then expressing the difference as a percentage of the air-dried mass. The treatments were assigned to the pots using a completely randomised design. Six replicates of each treatment were used.

The treatments were:

(1) Control – Pots were watered to a mass equal to 75% of field capacity, every second day.

(2) Treatment 1 – The pots were watered a mass equal to 50% of field capacity every second day.

(3) Treatment 2 – The pots were watered a mass equal to 25% of field capacity every second day.

The weight of the pots at field capacity was determined beforehand, and the required treatment weights were then calculated as a percentage of this weight. Before the application of each treatment the pots were weighed individually after which, water was added to a mass equal to the desired percentage of field capacity.

Ten seeds were planted in each pot. After establishment the seedlings in each pot were thinned out to three uniformly sized plants per pot. The pots were watered to field capacity every second day, and the plants were left to reach maturity. The plants were then all cut to the same height, and the application of the water stress treatments commenced. Data collected were seed mass and dry matter production. Only one harvest was made at the end of the season, which coincided with seed maturity.

An analysis of variance with the ANOVA model (Statistical Analysis Systems 2001) was used to determine the significance between different treatments. Means and standard deviations (SD) were calculated. Significance of difference (5%) between means was determined by multiple comparisons using the Tukey t-test (Samuels 1989).

Results and Discussions

According to the data (Table 1), it is clear that the water stress treatments had a negative influence on the dry matter yield of *U. brachyura.* When treatments 1 and 2 are compared to the control, reductions in dry matter production of 46 and 43% respectively were found (figure. 1). Seed production of treatments 1 and 2 were also lower than that of the control treatment (figure. 2).

Table 1. Seed and dry matter production of *U. brachyura* as influenced by water stress.

		Dry matter production	Seed production
Treatments	*Rep.*	*Dry mass (g/pot)*	*Seed mass (g/pot)*
Control(75%)	1	2.24	0.895
	2	4.03	1.158
	3	5.70	2.795
	4	4.01	0.900
	5	4.85	1.229
	6	4.92	1.226
Treatment1(50%)	1	2.86	0.637
	2	1.60	0.622
	3	2.92	1.023
	4	1.77	0.347
	5	2.80	1.092
	6	1.88	0.568
Treatment 2(25%)	1	3.54	0.207
	2	1.59	0.409
	3	1.75	0.404
	4	1.96	0.292
	5	2.89	0.599
	6	2.87	0.133

Control treatment – Pots were watered to 75% field capacity
Treatment 1 – Pots were watered to 50% field capacity
Treatment 2 – Pots were watered to 25% field capacity

The statistical analysis shows that treatments 1and 2 yielded significantly (P<0.05) less dry material (Table 1, Fig. 2) than the control treatment, although there were no significant differences between treatment 1 and treatment 2.

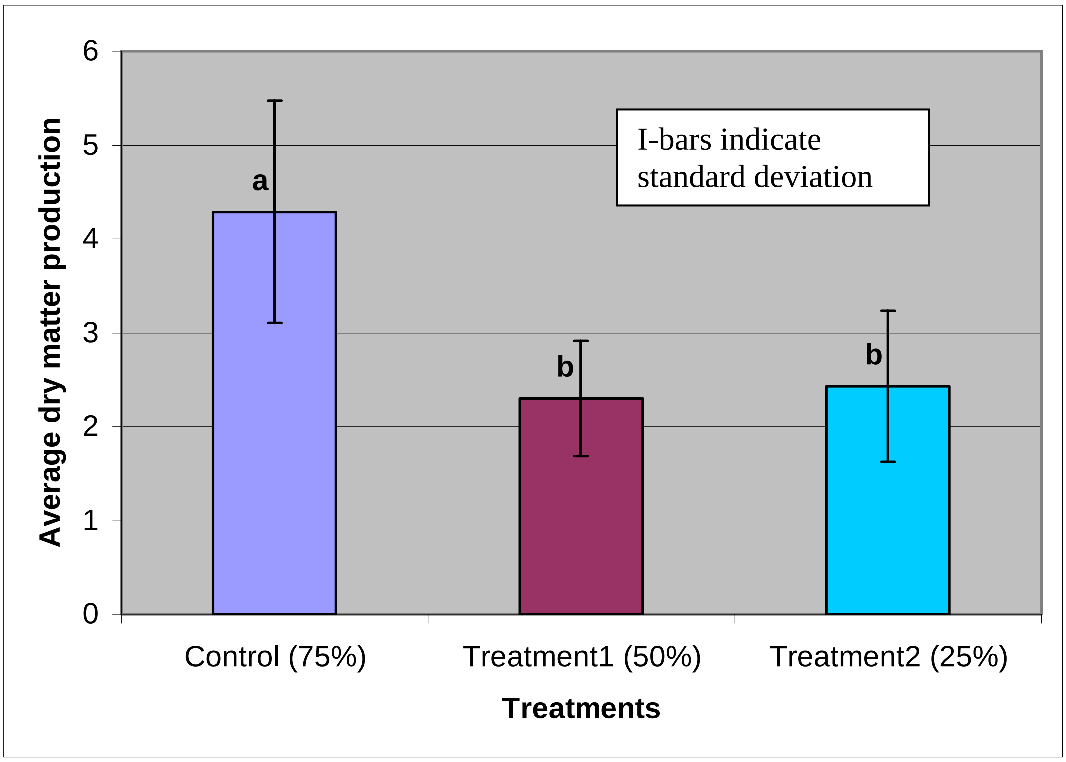

Figure 1. The average dry matter production of *U. brachyura* as influenced by water stress. Different letter, data labels, indicates significant differences

Significant (P<0.05) differences were also found between the treatments in terms of seed production. The control treatment had a 91% higher seed production than treatment 1, while the seed production of treatment 2 was 52% lower than that of treatment 1 (figure. 2).

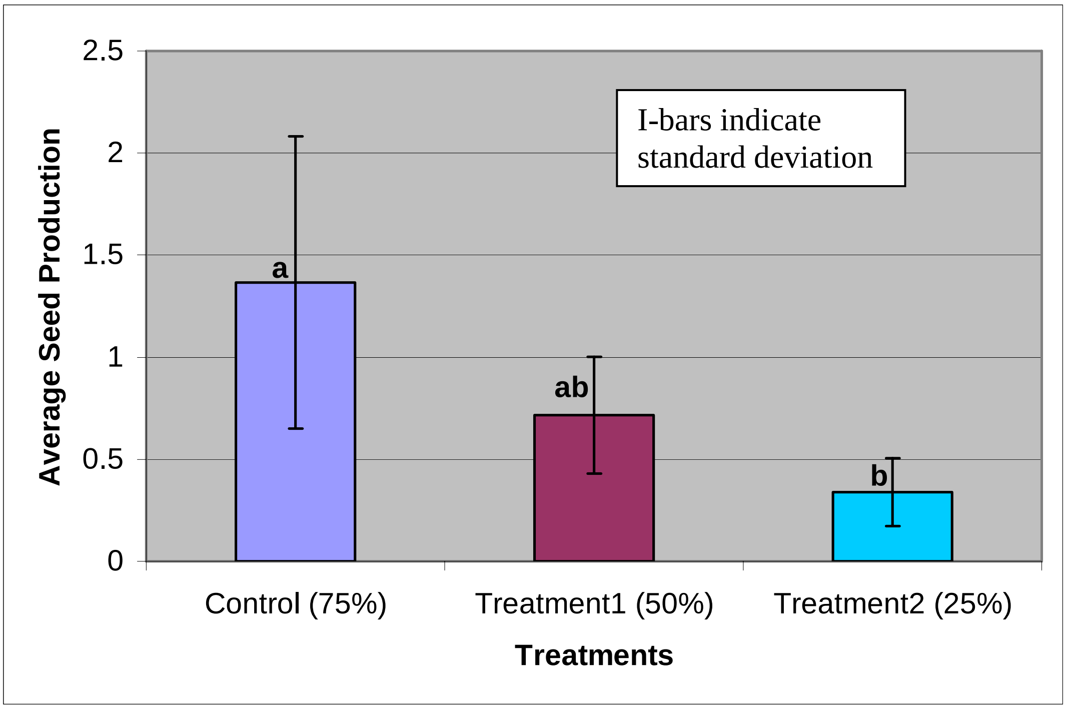

Figure 2. The average seed production of *U. brachyura* as influenced by water stress. Different letter, data labels, indicates significant differences

Conclusions

Water deficits had a definite negative influence on the dry matter production and the seed production of *U. brachyura.* When the amount of water applied decreased from 75% of field capacity to 50% of field capacity, a drop in dry matter production of 46% was registered. When even less water was applied (25% of field capacity), dry matter production did not decline significantly any further. The difference in seed production between the control treatment and treatment 1 was 48%. Seed production of treatment 2 was a further 52% lower than that of treatment 1. Water stress could thus have a strong negative impact on the successful re-establishment of this annual species on a volunteer basis.

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Chapter 6

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Production and quality characteristics of *Urochloa brachyura* (Hack.) Stapf.

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Urochloa brachyura is an annual tropical grass collected in Gauteng Province and selected for yield and quality. The potential use of this species in animal production systems and rehabilitation practices was first identified by Pieterse (1999), and is now being evaluated further. In this study, *Urochloa brachyura* was evaluated for production and quality. A trial to evaluate dry matter production over three seasons was conducted in Pretoria. Representative samples were analysed for crude protein content and *in vitro* digestibility. The influence of four N-levels (0, 40, 80 and 120 kg N/ha) on yield and digestibility were evaluated in a separate trial. The potential seed production was also evaluated over two seasons. Dry matter production results confirm results reported by Pieterse (1999), with an average total production of 14.3 t/ha, a digestibility of 74.9%, and a crude protein content of 12.3%. Nitrogen fertilization had no significant effect on dry matter production or digestibility. An average of 305kg seed/ha/season was produced over two seasons. The aim of this study was to confirm results obtained by Pieterse (1999), and to identify *U. brachyura* as being nutritious, high yielding, and capable of producing commercial seed yields.

Keywords: crude protein content, digestibility, dry matter production, seed production.

Introduction

Agriculture in South Africa is interdependent with other economic factors such as, energy prices, interests rates, exchange rates, and markets. The unpredictable agricultural environment in recent years has led to a shift in farming in general, aiming at diversification to reduce potential risk at farm level. The inability of South Africa to compete profitably on international grain markets and the relatively low demand for grain crops in South Africa has resulted in farmers looking for alternatives. In most farming areas forage crops were considered less important than grain crops. This attitude was common in times when returns from grain exceeded returns from livestock. However, the profitability of growing grain, compared to forage crops, needs to be carefully re-examined and decisions made accordingly.

Optimising pasture use requires specific information on pasture production potential (kg DM/ha/month and year), pasture quality (in MJ metabolizable energy per kg dry matter (MJ ME/kg DM), and animal requirements (kg DM/animal/month/year) (Van Houtert and Sykes 1999). This information could then be used as a management tool to ensure that monthly feed requirements of the herd match the total monthly pasture production on the farm as closely as possible (Cros *et al*. 2001). The production potential and quality characteristics of forage crops are, therefore, very important considerations when selecting a species to ensure the best possible performance and profit.

When the quality of forage is evaluated, the digestibility, protein content and energy content are important parameters. Digestibility relates to that proportion of food, which is not excreted in the faeces, and is assumed to be absorbed by the animal. Digestibility decreases as plants mature due to the formation of extra lignin. Whiteman (1980) found that the percentage digestible cellulose decreased as the percentage lignin in the cellulose component increased. According to Minson (1971) the digestibility of tropical grasses decreased with 0.1 digestibility units per day as plants matured. The digestibility of most forage crop ranges from a low of 40% for straw, to a high of over 75% with temperate pastures (Stuart 2002). When the digestibility of a feed is high the metabolisable energy content of the feed, which is the energy available to an animal, after accounting for the energy losses in faeces, urine and methane, will also be high. The protein content of forage plays a major role in determining animal production, and crops differ in their average expected protein content. Protein content declines with maturity in plants. Whiteman (1980) found that the crude protein content was highly soluble during the early period of rapid growth, but declined rapidly, as the grass matured and the proportion of cell content decreased. Gomide *et al.* (1969), who studied the influence of nitrogen fertilization on tropical grasses, found that N fertilization increased the N content of grass and that most of the increase occurred soon after the application of N and declined as the plants matured.

In this study, *Urochloa brachyura* was evaluated for production and quality. *U. brachyura* is a tufted annual tropical grass native to South Africa. It produces an abundance of leafy material and has a fast low growing habit. It was selected for its high yield and quality characteristics in the Gauteng region. Gibbs Russle *et al.* (1990) describe *U. brachyura* as an annual, growing 200-1200mm high, which flowers from October to April. The potential use of this species in animal production systems and rehabilitation practices was first identified by Pieterse (1999), and is now being evaluated further. Pieterse (1999), who evaluated 20 different grasses for production and quality, found that within two weeks of germination the development of *U. brachyura* seedlings far exceeded the others and that its yield at the first harvest was significantly higher than any other species. *U. brachyura* was also found to have a digestibility of +- 82%, with a crude protein content of +- 10.7%. The potential dry matter production was determined to be more than 15 t/ha, in comparison with the production of *U. mosambicencis* cv Nixon, a perennial, which was found to be less than 30% of that of *U. brachyura.* Because it is an annual, it may also have potential for use in rotational practices where it can produce high quality forage over a short period of time. According to Dickinson *et al.* (1997) the dry matter production of *Eragrostis tef*, which is also an annual, could be between 2-8 t/ha with a protein content of 8-11% and a digestibility of 55-60%. When compared to other sub-tropical grasses in terms of production and quality *U. brachyura*, therefore, shows great potential.

The aims of this study were to confirm results obtained by Pieterse (1999), to identify *U. brachyura* as being nutritious and high yielding, and to determine whether commercial seed production would be a proposition.

Materials and methods

Site

The trials were carried out on the Hatfield Experimental Farm of the University of Pretoria. The farm is situated 1353m above sea level, at the coordinates 25° 45' South and 28° 16' East, in a summer rainfall area with a long-term mean annual precipitation of 708mm. The soil form is Hutton (MacVicar *et al.* 1997) with a weak structure and a homogenous red colour, and is non-calciferous. It is described as a sand-clay-loam with 20%-35% clay content.

Layout

Three separate trials were conducted. Trial 1 was a dry matter production trial, where yield and quality were evaluated over three years. Trial 2 evaluated the influence of four N-levels on dry matter production and digestibility, and trial 3 was a seed production trial.

Trial 1

In the 2000/2001-season *U. brachyura* was planted using four different planting dates (October, November, December and January). The area used was level and homogenous in terms of soil and topography, and divided into 12 equally sized (12 m^2) plots. The allocation of the treatments was according to a completely randomised block design, with three replicates for each treatment. Seed was sown (by hand) on top of the soil to a firm and clean seedbed, and then compacted. A seeding density of 12 kg/ha was used. Due to poor germination and establishment, only the December planting could be used for the determination of yield and quality. Production, or pasture availability, was determined by clipping two quadrates (1m^2 each) in each replicate in February. After clipping the plots were mown, to evaluate regrowth in April. Plots received 100 kg N/ha in the form of limestone ammonium nitrate (LAN 28%). Samples of both clippings (late-summer and winter) were taken and evaluated for quality. The November planting only germinated and established the next season and was evaluated for production and quality in 2001/2002. In 2002/2003 a new trial was planted using two planting dates (December and February). Plot sizes were increased to 49m^2 with 4 replicates. The plots again received 100 kg N/ha in the form of limestone ammonium nitrate (LAN 28%). The seed was sown in rows (50cm row spacing) approximately 30mm deep, with a planting density of 12 kg seed/ha. The seed used in this experiment had a post-harvest age of 12-months. A heat treatment of 45°C for 3 weeks had been applied to the seed to improve germination. This treatment had been found in a previous experiment (Roselt *et al.* 2005) to improve the germination of *U. brachyura*. Dry matter production was evaluated by taking clippings in summer and autumn. Samples of all clippings were evaluated for crude protein and digestibility. Crude protein was calculated (% N × 6.25) after % N was determined using the Kjeldahl technique (AOAC, 1995), while the *in vitro* digestibility of organic matter (OM) was determined using the technique described by Tilley & Terry (1963) as modified by Engels *et al.* (1981).

Trial 2

The influence of four N-levels on yield and digestibility was evaluated by planting *U. brachyura*, in December 2000, and applying four N-treatments after germination. The treatments were 0,40,80 and 120 kg N/ha applied in the form of limestone ammonium nitrate (28%). Treatments were applied to the 16 plots (12m^2 each) using a completely randomised block design with four replications. 12 kg seed/ha was planted in 50cm rows. The area used was level and homogenous in terms of soil and topography. The effects of such factors could, therefore, be discounted and differences in terms of production and quality could, therefore, be ascribed to treatment differences.

The trial was planted in December, and the first clippings for the determination of dry matter production were made in February. Samples for quality analysis were taken in February and July. Quality parameters were determined as in Trial 1.

An analysis of variance with the ANOVA model (Statistical Analysis Systems 2001) was used to determine the significance between different treatments. Means and standard deviations (SD) were calculated. Significance of difference (5%) between means was determined by multiple comparisons using Tukey's t-test (Samuels 1989).

Trial 3

For the purpose of seed production in the 2001/2002-season, *U. brachyura* was established on two plots of 0.0435 ha each. Seed was planted mechanically using a wheat-planter, at 25 kg seed/ha (high seeding rate due to poor quality of seed used). After establishment, a nitrogen application of 100 kg N/ha was applied in the form of limestone ammonium nitrate (LAN 28%). The seed was harvested using a brush-harvester, and the first harvest was taken when seeds were ripe and started to shed. Four harvests were taken in all. In the 2002/2003-season a seed production plot was again established, with a total area of 0.1456 ha. The seed used in this production had a post-harvest age of 12-months and received a heat treatment of 45°C for 3 weeks to improve germination. A planting density of 12 kg seed/ha was used. The same planting and harvesting techniques were used. Three harvests were taken from this crop, and after harvesting; the seed was cleaned and dried to be stored at 5°C. The wet and dry mass of each harvest were determined and pooled together to determine total production.

Results and Discussions

Trial 1

Due to the poor germination and establishment only data from the December planting in the 2000/2001-season could be used. This can probably be ascribed to freshly harvested *U. brachyura* seed being dormant. It is, therefore, advisable to only use seed that was subjected to an after-ripening period or which has received a temperature treatment to shorten the after-ripening period. Good yields were, however, obtained from the December planting in 2000/2001 as a total average dry matter production of 14.3 t/ha was measured. Table 1. illustrates the average dry matter production data of *U. brachyura* as determined over three seasons. These results confirm results obtained by Pieterse (1999), who reported the dry matter production of *U. brachyura* to be approximately 15 t/ha.

Table 1. The dry matter production of *U. brachyura* as determined over three seasons.

	Dry matter production (t/ha)		
Season/ planting date	First cut	Second cut	Total yield
2000/2001 (December 2000)	9.20	5.10	14.30
2001/2002 (November 2001)	10.70	4.96	15.66
2002/2003 (December2002)	8.40	4.60	13.00
Average	**9.43**	**4.89**	**14.32**

After the second cut plants were left to produce seed and a third cut was not made.

Production data for February 2003 planting were lost and are not presented here.

The quality characteristics of *U. brachyura,* as determined over the three seasons, are summarized in Table 2. These indicate that *U. brachyura* had an extremely high digestibility in summer, which, did not drop to unacceptable levels in autumn and winter. The crude protein content was also lower in autumn/winter than in summer, but again did not drop to unacceptable levels (Table 2.). These quality data confirm results obtained by Pieterse (1999).

Table 2. The crude protein (CP) content and *in vitro* digestibility (%) of *U. brachyura* as determined over three seasons.

	***In vitro* digestibility (%)**		**Percentage crude protein (%CP)**	
Season	**Summer**	**Autumn**	**Summer**	**Autumn**
2000/01	78%(Feb)	53%(July)	13%(Feb)	9.3%(July)
2001/02	70.2%(Feb)	62%(Apr)	11%(Feb)	7.6%(Apr)
2002/03	76.6%(Feb)	55%(Apr)	13%(Feb)	8.4%(Apr)
Average	**74.9%**	**56.6%**	**12.3%**	**8.4%**

Trial 2

Statistical analyses indicated that no significant differences could be found between the different N treatments in terms of either dry matter yield or digestibility (Table 3.). Nitrogen fertilization had, therefore, no apparent effect on the dry matter production or *in vitro* digestibility of *U. brachyura,* although it probably did influence crude protein content, as reported by numerous authors (Rethman 1990). This lack of a strong response to N fertilization is not unusual in annual grass pasture species, where the seedbed preparation often involves a fallow, clean cultivation period, or in the establishment phase of perennial grasses.

Table 3. The influence of different levels of N fertilization on dry matter yield and digestibility of *U. brachyura.*

Treatment	Dry matter Yield (t/ha)	*In vitro* digestibility (%)	
		Autumn	Winter
0 kg N/ha	5.40 [a]	63.6% [b]	54.2% [c]
40 kg N/ha	4.99 [a]	63.4% [b]	52.9% [c]
80 kg N/ha	4.68 [a]	64.6% [b]	51.8% [c]
120 kg N/ha	5.30 [a]	62.7% [b]	49% [c]

Values in columns with the same superscript do not differ significantly. Significant differences were determined using a standard t-test where a P-value <0.05 indicated significance.

Trial 3

U. brachyura produces high seed yields. Care must, however, be taken to ensure harvesting at the right time when seeds are mature and start to shed, to avoid loss of seed due to shedding, or the harvesting of immature seed. In Figure 1. the seed production quantities harvested over two seasons are presented, revealing the potential of *U. brachyura*. Four harvests were taken in 2001/2002 while three were taken in 2002/2003, yielding 333.7 and 276.8 kg seed/ha respectively.

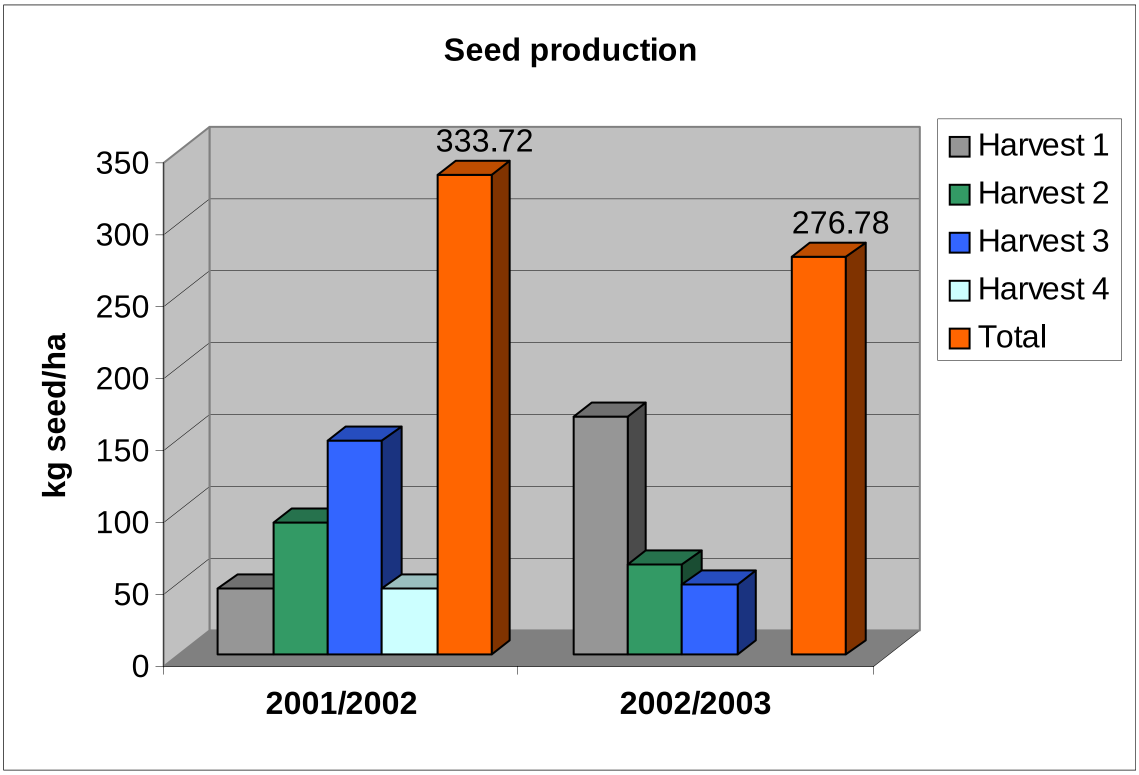

Figure 1. Seed production potential of *U. brachyura* over two seasons.

Conclusion

No apparent response to different N-levels could be determined in terms of production or digestibility. This lack of a strong response to N fertilization is not unusual in annual grass pasture species where the seedbed preparation often involves a fallow clean cultivation period, as was the case in this experiment (Personal communication*). According to the quality and production data obtained in this experiment, it can be concluded that *U. brachyura* is highly nutritious and has a very good seed and dry matter production potential. The data confirm results by Pieterse (1999) and *U. brachyura* can, therefore, be identified as a promising species for use in both reclamation and animal production systems. More research on its adaptability to different climates and soils, and its reaction to different levels of fertilizer will, however, need to be done, before this potential will be fully realized.

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Chapter 7

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

The influence of Na_2SO_4-dominated saline mine water on the germination and yield of *Urochloa brachyura* (Hack.) Stapf.

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The use of saline mine water for the irrigation of agricultural crops is a promising technology that could add value through agricultural production and the utilization of mine effluent, which may not be released into public streams. *U. brachyura* is an annual grass species identified as having great potential to be used in rehabilitation practices due to its fast, low growing habit, high yield and quality. The objective of this investigation was to determine the influence of saline mine water on the dry matter production and germination of *U. brachyura*, thereby, testing its suitability for irrigation with saline mine water. The experiment was conducted as a pot trial under glasshouse conditions. The plants were watered to field capacity, every second day. Na_2SO_4-dominated saline mine water from Syferfontein Colliery mine near Witbank was used as treatment, with tap water as control. Data collected included dry matter production and germination performance. Results indicate that there were no significant differences in terms of germination when saline mine water was used instead of tap water. Dry matter production where saline mine water was used, was, however, significantly higher than on the control treatment. No negative influence on dry matter production or germination, due to saline mine water could be found. *U. brachyura* is, therefore, identified as being suitable to be irrigated with saline mine water.

Keywords: germination, rehabilitation, saline mine water, yield.

Introduction

U. brachyura is a tufted annual tropical grass, native to South Africa. It was selected for its high yield and quality characteristics in the Gauteng province (Pieterse 1999), and shows great promise for the use in mine rehabilitation practices. In such situations the aim is to stabilize the landform with vegetation by establishing a good ground cover as quickly as possible, to reduce surface erosion on steep slopes and to control water runoff. According to Lyle (1987) the short-term goal of revegetation during surface mine reclamation is to control soil erosion quickly by using fast-growing plants, and that the long-term goal is to establish a crop that would benefit the landowner. *U. brachyura* is indeed a fast low growing species that produces an abundance of leafy material. Pieterse (1999) also identified *U. brachyura* as having great potential for the use in animal production systems. In that investigation it was reported that *U. brachyura* had a digestibility of +- 82%, with a crude protein content of +-10.7%. These characteristics, together with its low growing habit, makes *U. brachyura* suitable to be grazed by cattle and sheep. *U. brachyura* has, furthermore, a potential dry matter production of more than 15 t/ha.
Gibbs Russle *et al.* (1990) describe *U. brachyura* as an annual, growing 200-1200mm high, which flowers from October to April, which is well adapted in Savanna, Grassland and Nama-Karoo biomes.

In the mining of minerals, large volumes of minewater are generated with adverse effects on the already scarce water resources (Jovanovic *et al*. 2004). The disposal of such mine wastewater is a worldwide problem occurring wherever operating coal- and gold mines, as well as closed underground and opencast workings are found (Pulles *et al.* 1995). For instance, Kleinkopje Colliery (Witbank, Mpumalanga) currently has some 12 million m^3 of water stored underground, and it is estimated that the generated volume is in the order of 14 ML d^{-1} (Annandale *et al.* 2002). Annandale (2002) stated that, depending on the cropping system, this amount of water could sustain an irrigated system of 500-700 ha. There are a number of other coal mines in the Mpumalanga Highveld region. Annandale (2002) estimated that if 30 of the other mines generate water at a similar rate as Kleinkopje Colliery, then a potential exists to irrigate some 15,000-20,000 ha.

The chemical properties of wastewater emanating from the different mines depend largely on the geological properties of the coal, gold ore and other geological material with which waters come into contact. The concentrations of salts and other constituents frequently render such waters unsuitable for direct discharge to the river systems except in periods of high rainfall when an adequate dilution capacity is present and controlled release is permitted (Jovanovic *et al.* 2002). Annandale (1998) explained that by removing soil and blasting through rock to get to the coal, as at the Kromdraai opencast mine in Mpumalanga, the existing strata are disturbed and after rehabilitation, the system is then porous, allowing water to seep through. As the rock strata contain pyrite (FeS_2), the percolating water is acidified to pH levels as low as 2.5, making it useless for irrigation and unacceptable for return to the environment. This problem can be overcome by installing a liming plant, where the iron precipitates out as “yellow boy” slurry, which is periodically removed. Water leaving the liming plant has a pH of approximately seven, but is saline. Jovanovic *et al.* (1998) investigated the possible use of this lime-treated acid mine drainage for irrigation of agricultural crops. They found that the saline mine water proved to be an additional resource in mining areas, particularly where prolonged drought periods are likely to occur. Using this water could partially solve water shortage problems in these areas.

Considerable yield increases were found where crops were irrigated with lime-treated acid mine drainage, compared to rainfed cropping. Jovanovic *et al*.

(1998) concluded that large amounts of waste water could possibly be utilised for irrigation of high potential soils on the highveld. By filtering of saline water through the soil, and consequent precipitation of gypsum in the profile, environmental pollution could be limited. Jovanovic *et al.* (1998) identified crops such as soybeans, cowpeas, lucerne, pearl millet, winter cereals, fescue and subtropical perennial species as suitable for irrigation with lime-treated acid mine drainage. It was further stated that fast-growing species that use a lot of water are recommended.

Beletse (2004) evaluated the performance of several planted pastures under irrigation with Na_2SO_4 rich mine effluent, from Syferfontein coalmine in Mpumalanga. In this study he found that Fescue (cv. Iewag), lucerne, and Fescue (cv. Demeter)(all temperate species) could be grown successfully under irrigation with Na_2SO_4 rich mine water, and that a satisfactory yield and forage quality could be obtained. Beletse (2004) concluded that irrigation with the Na_2SO_4 rich mine effluent water from the Syferfontein coalmine is sustainable for pasture production, although, certain species, such as *Eragrostis curvula* and *Pennisetum clandestinum* (tropical species), were not tolerant of the high amounts of sodium.

The objectives of this investigation were to determine the influence of saline mine water on the germination and dry matter yield of *U. brachyura*, and to establish if this species would be suitable to be irrigated with saline mine water dominated by sodium. With the potential which *U. brachyura* already holds for use in reclamation, tolerance for saline mine water irrigation would increase the possible scenarios.

Materials and Methods

Saline mine water

The water, used in this experiment, was collected from one of the irrigation dams at Syferfontein coalmine, close to Witbank. This water comes from underground water in pillared workings where opencast mining cannot proceed if the water is not removed. The water is saline, and is dominated by a high concentration of Na_2SO_4. Table 1. shows the chemical composition of the saline mine water used in this experiment.

Table 1. Saline mine water composition, Syferfontein coalmine (Mpumalanga) (Beletse 2004)

Chemical composition:	Evaporation dam north	Syferfontein coalmines
	Mar-02	Average 2000-2002
pH	9.1	9.16
Cond (uS cm^{-1})	2810	3368.5
TDS (mg l^{-1})	2061	2585.2
SS (mg l^{-1})	48	119.56
Cl (mg l^{-1})	20.7	28.22
SO_4 (mg l^{-1})	1030	1389.86
Na (mg l^{-1})	500	615.57
F (mg l^{-1})	1.09	1.03
Fe (mg l^{-1})	-	0.06
Al (mg l^{-1})	-	0.03
Tot Alk (mg l^{-1})	460	458
Ca (mg l^{-1})	20.1	35.54
Mg (mg l^{-1})	56.9	85.65
K (mg l^{-1})	-	18.01
B (mg l^{-1})	-	1.14

Experimental seed

The seed used in this experiment had a post-harvest age of 12-months. A heat treatment of 45°C for 3 weeks, had been applied to the seed to improve germination. This treatment had been found, in a previous experiment (Roselt *et al.* 2005*),* to improve the germination of *U. brachyura*. All seed used received the same treatment.

Germination experiment

A germination test was carried out according to the standard germination test procedure prescribed by the International Seed Testing Association (ISTA 1985). 100 seeds were placed in each petri-dish. Distilled water, which is normally used in germination tests, was replaced by saline mine water from Syferfontein coalmine. Six replicates for each treatment were used, and distilled water was used in the control treatment. 7.5 ml water (distilled or mine water) was added to each petri-dish. The germination trial was conducted at alternating temperatures of 30/20°C for a 16/8-hour cycle. The final evaluation was made after 21 days.

Dry matter production experiment

The experiment was conducted as a pot trial under glasshouse conditions. The pots were each filled with 12kg air-dried soil. The soil used was a Hutton soil form of weak structure and a homogenous red colour (MacVicar *et al.* 1997). The soil can be described as a sand-clay-loam with a 20-35% clay content. The treatments were assigned to the pots using a completely randomised design. Twelve replicates of each treatment were used. Ten seeds were planted in each pot. After establishment the seedlings in each pot were thinned out to three uniformly sized plants per pot. The pots were watered with tap water to field capacity every second day, and the plants were left to reach maturity. The plants were then all harvested to the same height, and the application of the water treatments commenced. Treatment A (control) received tap water every second day, while treatment B received saline mine water every second day. Data on dry matter production were collected with two harvests being taken during the season.

Statistical analysis

An analysis of variance with the ANOVA model (Statistical Analysis Systems 2001) was used to determine the significance between different treatments. Means and standard deviations (SD) were calculated. Significance of difference (5%) between means was determined by multiple comparisons using Tukey t-test (Samuels 1989).

Results and Discussions

A statistical analysis of the germination test data indicated that there were no significant differences between the saline water treatment and control. Figure

1. shows that neither at the first count (7days), nor the final count (21days), could any significant differences be found between treatments in terms of germination.

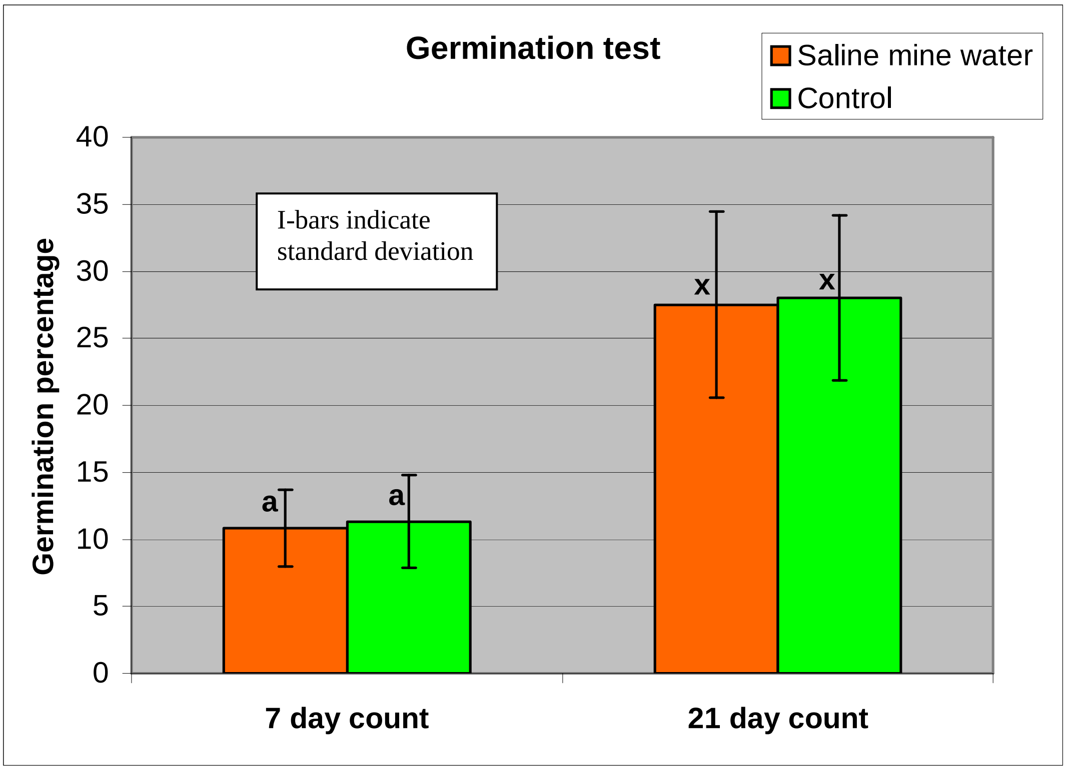

Figure 1. The influence of saline mine water on the germination of *U. brachyura.* Different letter, data labels, indicates significant differences.

According to the statistical analysis, however, significant differences do, however, exist in terms of dry matter production between the treatments. Figure 2. shows that the saline mine water treatments had a 35% higher dry matter production in the first cut and a 46% higher production in the second cut compared to the control treatment, where tap water was used. This significant difference in production is, however, unexpected and still needs to be explained, by conducting more experiments. At this stage it is clear that the dry matter production of *U. brachyura* was not negatively influenced by saline mine water.

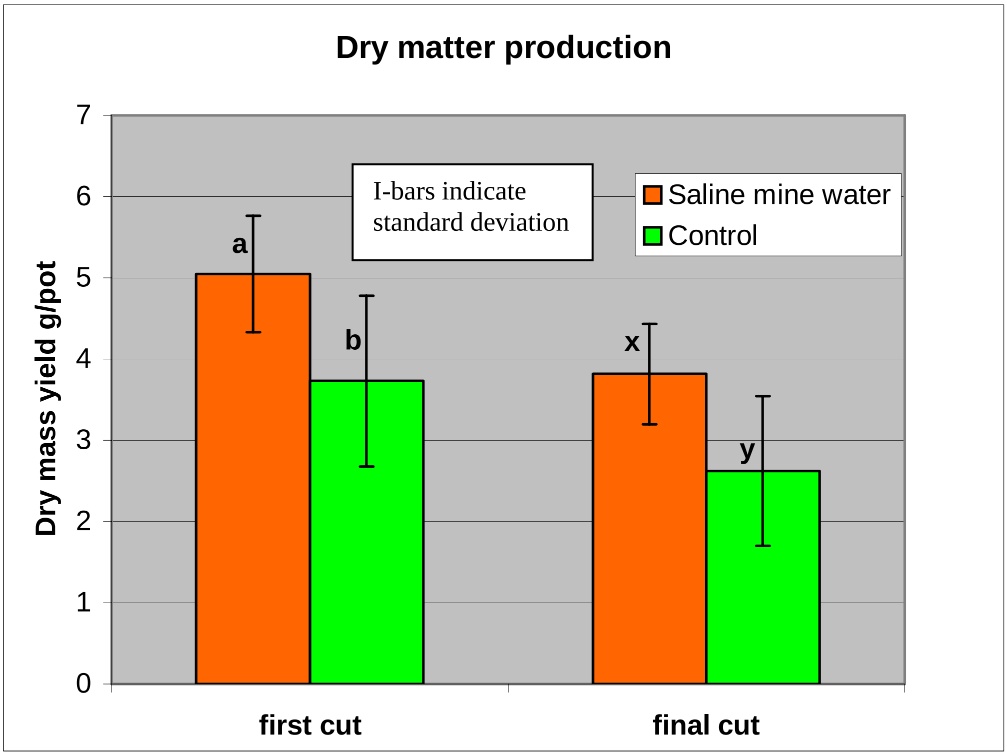

Figure 2. Dry-matter production of *U. brachyura* as influenced by saline mine water. Different letter, data labels, indicates significant differences

Conclusions

The objective of the experiment was to determine if *U. brachyura* could be irrigated with saline mine water without negatively affecting the germination or yield. According to the results, no negative influence on germination or dry matter yield could be found and the latter was actually positively influenced by irrigation with saline water. It can, therefore, be concluded that *U. brachyura* could be successfully irrigated with saline mine water.

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Chapter 8

General Conclusion and Recommendations

The need for an increase in livestock production in South Africa, and the reality of limited natural resources available, as discussed in chapter 1, places greater emphasis on the potential role of planted pastures in the future. Collapsing grain markets and the difficulty of profitable maize production, which is a common problem amongst farmers since 2004 - 2005, also places more pressure on farmers to look at alternatives to planting maize. More and more farmers consider converting their marginal soils to planted pastures, and only produce cash crops on their high potential soils. This growing phenomenon has led to the identification of *Urochloa brachyura* as a potential pasture species.

This annual tropical grass was initially identified for its yield and quality characteristics. Its growth habit, which, is fast and creeping, also identified a potential for use in mine rehabilitation practices where a quick stabilizing ground cover is needed to protect soil.

The objectives of this research project were to gather more information on the production and quality of *U. brachyura*, which, are very important considerations when selecting a species for animal production. The study was further aimed at increasing the germination performance of *U. brachyura*, which appeared to be very poor. The use of *U. brachyura* in rehabilitation practices was also evaluated in this study.

The first seed harvested in this study had a very poor germination, and it was believed that too high drying temperatures might have been the cause of the poor quality seed. The influence of different drying temperatures on seed quality was, therefore, evaluated in chapter 2. Results from this work confirmed that the seed quality of *U. brachyura* had not been affected by drying temperatures between 20 and 45°C. A closer examination of the seed that did not germinate, revealed that normal seedling growth had been replaced by a mass of fibrous root growth. This confirmed that poor germination performance could not be attributed to lack of viability, but was rather due to a form of post harvest dormancy. Ways of improving germination and breaking the dormancy were then evaluated in chapter 3. Several experiments had been carried out in order to improve germination.

No significant improvement in germination could be found. The first improvement in germination was observed when seed was subjected to a temperature treatment. This 45°C temperature treatment may improve the germination performance of *U. brachyura* seed to between 30 and 40% compared to <4% or 0% for the control (chapter 3).

In chapter 4, improving germination was further explored by investigating agronomic traits such as depth of sowing. The results of the experiment suggests that the optimum depth of sowing for *U. brachyura* appear to be at least 5mm with the highest emergence being recorded with 30mm of soil coverage. Such planting depths resulted in seedling emergence of up to 50%, as was the case in some replications of this experiment. Sowing on the soil surface should, therefore, preferably be avoided.

A further investigation was conducted in order to determine the reaction of *U. brachyura* to water stressed conditions, which, is the rule rather than the exception in South Africa. According to the data collected in chapter 5, it is clear that the water stress treatments had a negative influence on the dry matter yield of *U. brachyura.* Results also indicate that seed production was even more severely influenced by water stressed conditions. Water stress can thus have a strong negative impact on the successful re-establishments of this annual species.

During the determination of the production of *U. brachyura* in this study, several cuttings at different stages were made, which, were all analysed to determine the quality. The results indicate that *U. brachyura* is highly nutritious, and could definitely be incorporated in animal production systems on the basis of its high digestibility and protein content. The determination of dry matter production proved that *U. brachyura* can produce very high dry matter yields in a short period of time, which, makes this species suitable to be used in fodder flow programmes and to fill specific gaps that might occur during the season.

Seed production from *U. brachyura* would also be viable, as harvesting the seed proved to be very easy when using a brush harvester and the fact that large amounts of seed are produced. Judging the correct harvesting time is particularly difficult for *U. brachyura,* as is the case with most tropical grasses. Estimating the time when maximum yield of viable seed occurs is not entirely satisfactory, since seed usually attains maximum viability while still quite soft and vulnerable to mechanical damage and this is then reflected in poorer seed longevity in storage. At the same time it is important to remember that keeping ripe seed in the field is equivalent to storage under highly unfavourable conditions of temperature and humidity. The intention is, therefore, to judge when the rate of increase of ripe seeds from new inflorescences just balances the loss of high quality seed from older inflorescences.

The potential that *U. brachyura* already holds for the use in rehabilitation practices because of its fast, low growing habit, was further evaluated in chapter 7. The objective of the experiment was to determine the influence of saline mine water on the germination and dry matter production of *U. brachyura.* The results suggest that *U. brachyura* can successfully be irrigated with saline mine water. Neither germination nor yield were negatively influenced by the saline mine water. As much of the mine water of underground workings in the Mpumalanga area is saline, the potential use of *U. brachyura* under saline irrigation is enormous.

With the current situation in South Africa and the increasing importance of planted pastures, the selection, evaluation and development of highly productive grasses such as *U. brachyura* is very important. This study proved *U. brachyura* to possess characteristics that enable it to be used in a wide range of situations. Although more research is necessary to realize its full potential, adaptations and requirements, it can be concluded from the results of this project that *U. brachyura* can be used successfully in animal production systems and rehabilitation practises.