EVALUATION OF DIFFERENT TEMPERATE WINTER FODDER SPECIES (*FESTULOLIUM* HYBRIDS, *DACTYLIS SPECIES*, *LOLIUM* HYBRIDS) AND GRASS-LEGUME MIXTURES IN THE WARMER SUMMER RAINFALL AREAS OF SOUTH AFRICA

By

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DECLARATION

I hereby declare without stipulation that this research project titled “Evaluation of different temperate winter fodder species (*Festulolium* hybrids*, Dactylis species*, *Lolium* hybrids) and grass-legume mixtures in the warmer summer rainfall areas of South Africa” is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references and comply with the code of academic integrity, as well as other relevant policies, procedures, rules and regulations of University of Limpopo. I also confirm that this work has not been submitted before for any other degree at any other institution.

__________________ __________________

Student’s signature **Date**

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I wish to thank the Almighty God for his wisdom and guidance throughout this study; without His favour, I wouldn't have completed this research. I also express my innermost gratitude to my late parents who granted me the opportunity to further my studies, and may their soul rest in peace.

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DEDICATION

I dedicate my mini-dissertation work to my daughter, Zenenkosi Thandolwethu Penelope Kabine. I would like to extend special gratitude to my late parents, Moses and Grace Kabine, who encouraged me and gave me the strength of tenacity, my lovely siblings David, Joseph, Lucas and Sarah who never left my side and are very close to my heart.

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ABSTRACT

South Africa is regarded as a semi-arid area; only 28% of the country receives more than 600 mm rainfall recorded annually. Sustainable utilization of cool season fodder grasses in summer rainfall areas to produce winter animal feed remains a major problem. Farmers are affected by a shortage of adequate, good quality herbage for livestock during winter and dry periods on commercial farms.

The study aimed to evaluate and compare the production potential of six *Festulolium* hybrids, three *Dactylis species*, and five *Lolium* hybrids and three grass-legume mixtures in the summer rainfall area. A total of 17 cultivars were evaluated for their DM production under the treatment of different fertilizer levels on three planting dates (16 March 2011, 21 April 2011 and 4 April 2012). The study was carried out at Hygrotech Seed Company (Experimental site), Dewagensdrift in Moloto Village outside Pretoria in the Gauteng Province.

Data was collected on a monthly basis from sub-plots of 1 m x 1 m (m^2) in 51 plots of 1.5 m x 6 m (9 m^2), with nine rows that were 10 cm apart arranged under RCBD with three replicates per cultivar. Harvested fresh samples were taken, weighed, dried at 60ºC until they reached a constant dry weight and weighed to determine DM content. A Fischer's protected LSD at the 5 % level was performed to compare the treatment means.

Over a period of three years of study, it shows that the low fertilizer level resulted in the lowest DM production, with no significant difference occurring between medium and high fertilizer levels. To achieve optimum DM production with minimum cost medium fertilizer is recommended. The cultivars responded differently to the three different planting dates. The time of planting had an effect on DM production in winter. It is recommended that *Festulolium* hybrids and *Lolium* hybrids be planted earlier (March) for better DM production in winter.

Key words: *Annual ryegrass, cutting dates, dry matter production, fertilizer levels, perennial grass, planting dates*

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LIST OF ABBREVIATIONS

Abbreviation	Definition
ARC	Agricultural Research Council
NRF	National Research Foundation
DM	Dry Matter
LSD	Least Significant Deference
RCBD	Randomised Complete Block Design
SA	South Africa
USDA	United States Department of Agriculture
CP	Crude protein
TNC	Total Non-structural Carbohydrates
DMI	Dry Matter Intake
REML	Restricted Maximum Likelihood
GDP	Gross Domestic Products
ISCW	Institute for Soil, Climate and Water
LTA	Long Term Average
TDM	Total Dry Matter
LAN	Lime Ammonium Nitrate
DoA	Department of Agriculture
Kg	Kilogram
mm	millimeter
ha	hectare
cm	centimeter
P	Phosphorus
Ca	Calcium
Mg	Magnesium
Na	Sodium
C	Carbon
K	Potassium
N	Nitrogen
t	Tons

cv.	Cultivar
sp.	Species
spp.	Species
PD	Planting date
FPL	Festulolium pabulare loloid
FPF	Festulolium pabulare festucoid
LAN	Limestone ammonium nitrate
Fert.	Fertilizer
KCL	Potassium chloride

CHAPTER 1:

GENERAL INTRODUCTION

1.1 Background information

Sown pastures are the base for profitable milk production in some regions of South Africa (Meeske *et al*., 2006). The temperate climate, availability of water for irrigation and the all-year-round rainfall in some areas are some of the most important factors contributing to the inclusion of various grass species in the fodder flow program to these areas (Botha, 2003). It has been shown by Miller *et al*. (2001) that the selection of grasses for higher levels of total non-structural carbohydrates (TNC) might increase palatability, intake and milk production. The studies of Taweel *et al*. (2005) and Tas *et al*. (2005), however, did not confirm this. High quality ryegrass often has a low dry matter (DM) content which may restrict the intake of grass by dairy cows (Bargo *et al*., 2003).There is however, limited data available on the production potential and forage quality of the most recent cultivars of temperate winter fodder species under irrigation in the warmer summer rainfall areas. The aim of the study was to evaluate and compare the production potential of different cultivars of temperate winter fodder species (*Dactylis species*, *Festulolium* hybrids and *Lolium* hybrids*)* and grass-legume mixtures to yield a higher dry matter (DM) content than existing cultivars in terms of DM production under irrigation in warmer summer rainfall areas of South Africa. A total of seventeen cultivars, three *Dactylis species*, five *Lolium* hybrids, six *Festulolium* hybrids and three grass-legume mixtures were evaluated and compared in terms of monthly, seasonal and annual DM production over a period of three years.

1.2 Problem Statement

South Africa is regarded as a semi-arid area; only 28 % of the country receives more than 600 mm rainfall annually (Schulze, 1997). As rainfall is the limiting environmental factor that determines agricultural production in the arid and semi-arid areas (Snyman, 1998), sustainable utilization of cool season fodder grasses in summer rainfall areas to produce winter animal feed remains a major problem. According to Coetzee (2012), the number of dairy farmers in SA has decreased by 36 % from January 2007 to January 2012.

Farmers are affected by a shortage of adequate, good quality herbage for livestock during winter and dry periods on commercial farms (Fair, 1989). Animals lose weight in winter, which leads to low reproduction, low production of milk, mutton and meat production. The demand for high animal production in an alternative way to conventional rearing has increased globally in recent years (Nilze'n *et al*., 2001; Walshe *et al*., 2006, Shongwe *et al*., 2007). The impact of unsustainable beef and dairy production due to winter and dry periods often entices less GDP (Gross Domestic Products) for the country. This is due to high imports of meat especially due to scarce nutritional feeding systems (Anon, 2004).

1.3 Motivation of the study

Pasture form the basis for profitable and intensive meat and milk production in some regions of South Africa (Meeske *et al*., 2006). Reed (1996), Callow *at al*. (2003) and Nie *et al*. (2008) reported that Tall fescue (*Lolium arundinaceum*) and Cocksfoot (*Dactylis glomerata*) are alternative temperate perennial grasses that could improve the persistence and stress tolerance. The strategic utilization of different types of temperate grasses like annual rye grass (*Lolium multiforum Lam*.: Italian or Westerwolds rye grasses) and perennial rye grass (*Lolium perenne L*.) increase the seasonal DM production of the pastures offered to dairy cattle (Botha *et al*., 2007). With increasing human population, agriculture became the dominant source for survival. The most direct way of achieving this on land set aside for animal production, is to increase forage production, accompanied by an increase in livestock production (Tainton, 2000).

Consequently, farmers have to make decisions on species (annual or perennial) and type (Italian or Westerwolds) of ryegrass to use in their production system. These decisions may have a major impact on the profitability of farming. Unfortunately, limited information is available on newer winter growing species, their adaptability and utilization by grazing animals (Botha *et al*., 2007). One of the biggest challenges for the animal industry is the selection of crops that will be able to produce in most areas of South Africa, with limited irrigation. It is further important to choose the correct cultivars, the correct planting date and the correct utilizing stage of the fodder grasses.

1.4 Purpose of the study

It was stated under the research problem that the production potential and forage quality of different perennial winter fodder species under irrigation in summer rainfall areas have never been evaluated and compared.

1.4.1 The aim

The aim of this study was to evaluate and compare the production potential of different temperate winter fodder species and mixtures to provide better understanding on their usage under irrigation for improved sustained pasture quantity and quality in the warmer summer rainfall areas of SA.

1.4.2 The objectives

The objectives of this study were as follows:

(i) To determine the effect of different fertilization levels on the DM production of *Festulolium* hybrids, *Dactylis species*, *Lolium* hybrids and grass-legume mixture species under irrigation in the warmer summer rainfall areas of SA.

(ii) To evaluate the DM production of *Festulolium* hybrids, *Dactylis species*, *Lolium* hybrids and grass-legume mixture species under irrigation in the warmer summer rainfall areas of SA.

(iii) To determine the effect of different planting dates on mid-summer DM production of *Festulolium* hybrids, *Dactylis species*, *Lolium* hybrids and grass-legume mixture cultivars under irrigation in the warmer summer rainfall areas of SA.

(iv) To determine the effect of planting dates on mid-winter DM production of *Festulolium* hybrids, *Dactylis species*, *Lolium* hybrids and grass-legume mixture cultivars under irrigation in the warmer summer rainfall areas of SA.

CHAPTER 2:

LITERATURE REVIEW

2.1 Impact of climate change on dairy cattle production in South Africa

There is growing evidence that climate changes will cause considerable damage to the agricultural sector worldwide. In Africa, the livestock sector will suffer the most from the adverse effects of climate change because the major proportion of agricultural production is from livestock. According to Seo and Mendelsohn (2006), environmental warming will be harmful to livestock owners, especially cattle owners. Currently the biggest concern for farmers is water scarcity, and it would remain a major concern in future.

A study conducted by the World Bank and the McKinsey Group, showed that South Africa could experience a water shortage of close to 2.7 million m^3 by 2030 (2030 Water Resources Group, 2009). Economic losses from reduced animal performance as a result of adverse climate changes are likely to exceed those associated with death losses (Mader, 2003). Increased performance expected from livestock, coupled with sub-optimal environment conditions, will increase animal vulnerability and risk (Hahn, 1999). Klinedinst *et al*., (1993) observed that abnormally high temperatures may reduce milk production by up to 20 % and conception rates by as much as 35 % in dairy cattle.

Most of the work on the impact of climate change has focused on areas such as water resources, rangeland ecosystems and human health, while in agriculture studies have focused more on the impact on major crops such as grains. While these assessments are of importance, they have small contributions to the South African agricultural economy which is dominated by animal production, with dairy production accounting for about 20 % of the total number of cattle in South Africa (DoA, 2008). The dairy industry is one of the largest employers in the agricultural sector. Possible effects (both direct and indirect) of climate change on dairy cattle in SA have not been thoroughly investigated. The aim of this study was to evaluate the production potential of different temperate winter fodder species in the warmer summer rainfall areas of SA. This will help to create more profitable dairy businesses, improve the competitiveness of the South African dairy sector, as well as contribute towards a reduction in climate change.

2.2 The need to improve animal production in South Africa.

2.2.1 Lack of winter feed

According to Dannhauser (1991), shortage of adequate good quality herbage during the winter months is one of the biggest problems confronting the stock farmer in the summer rainfall areas. The issue of low quality feed during winter and spring is common to many livestock farmers (Fair, 1989). Animal scientists agree that poor winter feed is responsible for the generally low animal production in SA. The impact of unsustainable beef and dairy production due to winter and dry periods often entices less GDP (Gross Domestic Products) for the country. This is due to high imports of meat due to scarce nutritional feeding systems (Anon, 2004). Previously disadvantaged communities are then unable to access quality meat due to higher meat prices and as a result, experience health problems (lack of iron in their diet) (Anon, 2004).

2.2.2 Alternative winter feeding strategies:

2.2.2.1 Hay

According to Engelbrecht *et al*. (2004) hay plays an important part in most fodder-flow programs. Hay production requires higher financial inputs than foggage and forage. Because of the high running costs, hay should be used for high-producing animals or when no other grazing is available. Hay is usually fed in the late winter months, before the veld is ready for grazing. Hay can also be used as drought reserve. Good-quality hay may be used for any kind of animal. When hay is produced, the correct forage species must be used, it must be cut at the right time and correct fertilization must be practiced. The choice of species depends on the environment, availability of irrigation and type of animal.

2.2.2.2 Silage

Engelbrecht *et al*. (2004) mentioned that in regions where winters are cold and dry, it is a usual practice to conserve forages. Silage is made of seasonal surpluses (mainly of maize) that occur on most intensively farmed farms. The advantages of silage above that of hay, is that it is less dependent on the weather, has no fire hazard and quality is maintained for a longer period. The disadvantages include a poorer intake of dry matter, higher transport costs and lower acceptability to young animals. Silage is generally meant for high productive animals like dairy cattle and fat lambs and could be expensive on extensive beef cattle farms. When animals graze rested veld in winter, they do not adapt very well to being fed silage afterwards. Research indicated that cattle lost weight when they started feeding on silage after they had spent the winter on rested veld.

2.2.2.3 Crop residues

Crop residues offer great potential as a relatively cheap feed source for the livestock industry and is sometimes regarded as crucial for livestock survival in winter (Crichton *et al*., 1998 as cited by Van Zyl, 2006). However, farmers have tended to withdraw the more marginal soils from cash cropping due to the following limiting factors:

- A price - cost squeeze in cash cropping.
- Climatic risk like short, severe droughts especially in Limpopo.
- Soil restrictions, like acidity build up and aluminum toxicity.

This has resulted in a reduction in the availability of crop residues for livestock. Abandoned crop lands are often left to revert to secondary succession again or established with crops to compensate for the loss in crop residues. Minimum tillage cultivation practices on grain crop lands are gaining popularity. These practices inhabit the utilization of residues to a large extent, and this contributes further to the decrease in residues available for livestock (Van Zyl, 2006). Most parts of the semi-arid area, maize stalks make extremely important contribution to the forage requirements of the animals during winter, which is most difficult in Limpopo Province due to unpredictable low rainfall (Tainton, 2000).

2.3 Origin and cultivation of pasture species

2.3.1 Centre of diversity and domestication

Western Europe is the main centre of origin for the Poaceae (*Festuceae*) family (Wipff, 2002; Meyer and Watkins, 2003), which includes *Festulolium, Dactylis* and *Lolium* species. Annual rye grass, perennial rye grass and cocksfoot are native to Europe, temperate Asia and Northern Africa (Lamp *et al*., 2001). They were introduced to other temperate parts of the world, including North and South America, South Africa, New Zealand and Australia, because of their value as a pasture plant. They are defined as ‘cool season grasses’ because of their preferential adaptation to cool and moist environments (Romani *et al*., 2002). Perennial forage grasses are not domesticated in the strict sense as ‘wild’ collections are generally phenotypically indistinct from cultivated forms. The exception to this rule is annual ryegrass, which was selected from a continuum of *Lolium spp*. and now has species status as *L. multiflorum* (Casler and Duncan, 2003).

2.3.2 Fodder improvement

Factors which are considered when a pasture plant introduction is made include; adaptation to the environment; for example climatic conditions and soil factors; higher yields than the resident species and increased winter/autumn production; higher nutritive value/herbage quality; seedling vigour, even spread of growth during the growing season; persistence and tolerance to grazing; ability to combine with other grasses and legumes; adequate seed production; pest and disease resistance; no adverse effects to animals; herbicide tolerance and lower endophyte toxicity and increased seed yield (Oram and Lodge, 2003).

Irrigated fodder

There are approximately 80 species of commercially available species and cultivars which are used in South Africa (Klug and Arnott, 2000). Lucerne (*Medicago sativa*) is the main purpose grown irrigated fodder in South Africa, and is grown under irrigation throughout the country. Ryegrass (*Lolium multiflorum and L. perenne*) is cultivated on a large scale for pastures in the dairy industry. Many other species and numerous cultivars are available commercially and are provided in detail by Bartholomew (2000).

Imported fodder

In times of drought, the South African government traditionally assisted farmers in obtaining fodder by providing subsidies. According to the new drought policy (National Department of Agriculture, 1997), the fodder subsidies have been terminated in order to encourage farmers to build up their own forage reserves and to discourage them from retaining excessive stock numbers. Nonetheless, it is likely that some commercial farmers, and probably the government, will continue to import fodder in extreme drought conditions.

Constraints to pasture and fodder production and improvement

The principal constraints to pasture and fodder production in commercial areas are:

- Low and uncertain rainfall.
- Salinization of irrigable soils.
- Declining water quality.

The principal constraints to pasture and fodder production in communal areas are:

- Low and uncertain rainfall throughout most of the country
- Concern about exotics becoming problematic, which limits the introduction and testing of hardy species considered suited to the environmental and utilization rigours of the communal areas
- The availability and price of seeds for pasture/fodder improvement
- Considerable portions of the savanna vegetation types in the freehold farms are severely encroached by bush, but the costs of thinning/clearing generally outweigh the benefits in terms of increased carrying capacity.
- Conventionally, communal farmers do not retain exclusive use of their unfenced croplands after harvest for their own livestock, so limiting the opportunities and incentives for undersowing or alley cropping.

2.3.3 Beneficial attributes

The herbage yield and composition of *Festulolium species* and *Lolium species* are influenced by many environmental and climatic conditions, soil type, nutrients in the soil, fertilization and management, species and cultivars (Tas, 2006). Generally, pastures are most palatable, most easily digested and most nutritive earlier in the season when leaves are young (USDA, 2006b). Although the nutritive value of pasture declines with age, total yields increase, which results in a conflict between quality and yield. Taking this into consideration, early cutting of cool season grasses is probably the most cost-effective way of producing feed for both production and maintenance of stock, despite the sacrifices in total yield (Andrews, 1997).

2.4 Nutritive value of pasture species

Nutritive value relates to digestibility of herbage ingested by the animal, and the efficiency with which the digestion end products are used. The major determinants of the nutritive value of pastures are the botanical and morphological composition, the environment in which the pastures are grown, and the regrowth period or age of the herbage (Lambert *et al*., 2000).The stage of growth is the most important factor influencing composition and nutritive value of pasture herbage (McDonald *et al*., 2002). As the plant mature the DM and CP content decreases, and the fibre content increases.

2.5 Dry matter production of pasture species

The dry matter production or yield of a pasture species is determined by genetic factors, such as grass species and variety, and environmental factors, such as climate, soil type, fertilization level, and grazing management (Marais, 2001). The production of a pasture species varies due to three main factors: (1) the site class, which is defined by rainfall or irrigation, soil type, and elevation; (2) the quality of sward and (3) the supply of nitrogen (Castle, 1985).

2.6 Temperate winter fodder grass species

Annual and perennial ryegrasses are temperate grass species. Their primary growth period is in winter, so they can play an important role in producing winter forage in some parts of South Africa. According to Thom and Prestidge (1996), annual ryegrass (*Lolium multiflorum Lam*.) is capable of winter/early spring growth than perennial rye grass allowing dairy farmers to overcome feed shortages in mid-July to September. Annual ryegrass varieties, such as Italian ryegrass (*Lolium multiflorum* var. *italicum*) and Westerwolds ryegrass (*Lolium multiflorum* var. *westerwoldicum*) are established in pure swards to provide high quality fodder for animals (Botha *et al*. 2008, Botha and Gerber 2008, Van der Colf, 2010), forming an important part of fodder-flow systems in the Southern Cape. Annual ryegrass grows more rapidly at low temperatures than perennial ryegrass and has a higher soluble carbohydrate content (Reed, 1994). Lowe *et al*., (1999) stated that irrigated annual ryegrass pastures are highly productive both in terms of herbage produced and milk production/cow/ha.

According to Tas *et al*. (2005), perennial ryegrass has a high DM production/ha and produces a high nutritive value feed to dairy cows at low cost. According to Taweel, (2004), because of its productivity, palatability, digestibility and nutritive value, perennial ryegrass is the most widely used forage for feeding dairy cattle in temperate environments. The relatively poor digestibility of perennial ryegrass pastures in summer leads to the use of feed supplements to maintain dairy production (Smith *et al*., 1998). At an early stage of maturity, perennial ryegrass is highly digestible and has a high nutritive value in terms of energy and protein (Van Vuuren, 1993). However, despite its high nutritive value, perennial ryegrass has two main disadvantages: (1) it has an unbalanced energy/protein ratio and (2) its low DMI by high producing dairy cows (Bargo *et al*., 2003a).

2.6.1 Perennial ryegrass (*Lolium perenne)*

Description

Perennial ryegrass (*Lolium perenne)* is a cool season tussock-forming perennial grass with a fibrous root system that grows up to 60 cm high. Leaf blades are dark green, hairless, the upper surface is evenly ribbed and the lower surface is smooth and shiny. Length of leaf blade is up to 30 cm long and up to 7 mm wide. Young leaves are usually folded in the bud but occasionally rolled, particularly in young plants. Auricles are small and narrow. Ligules are white, translucent and short (Lamp *et al*., 2001).

Establishment

Perennial ryegrass will survive only in cool, wet conditions (750 mm +) in high altitude areas. It produces very well in the mountainous areas of KwaZulu-Natal and the Eastern Cape. The seeding rate, when planted in rows, is 10 - 15 kg/ha and when broadcasted with irrigation it is 20 - 25 kg/ha (Dannhauser, 1991). It can be planted in spring and early autumn.

Establishment limitations

Perennial ryegrass requires fertile soils, high levels of nitrogen fertilization, regular irrigation plus top management for it to establish better. It must get rain or frequent irrigation under hot and dry conditions (Fair, 1989).

Nutrient requirements

Perennial ryegrass grows best on fertile, well drained soils but has a wide range of soil adaptability, and tolerates both acidic and alkaline soils (pH range of 5.2 to 8.0) (Cool and Annaway, 2004). It responds well to applications of nitrogen (both as absolute N and N fixed by legumes) and phosphorus, and is moderately tolerant to acid soils although there is sensitivity to Al concentration when the soil pH is low (Waller and Sale, 2001). The P-content of the soil should be 25 mg/kg and the K-content 100 mg/kg. Nitrogen content should be applied at a rate of 250 kg N/ha to 400 kg N/ha, depending on rainfall and irrigation (Dannhauser, 1991).

Temperature requirements and tolerances

Perennial ryegrass is less tolerant to heat although there is variation between cultivars (Razmjoo *et al*., 1993). It is best adapted to a cool, moist climate where winterkill is not a problem. It is tolerant to cold winters and can maintain growth down to 4˚C. Generally, cultivars with poor winter hardiness are very early heading, while those with better winter hardiness are later heading (Humphreys, 1989). Perennial ryegrass is sensitive to drought (Garwood *et al*., 1979), which leads to a reduction in herbage production under a mild moisture deficit, and dormancy or death under a severe drought. Studies in both temperate (Waller *et al*., 1999) and subtropical areas (Lowe *et al*., 1999b) indicated that perennial ryegrass survival hot dry conditions by dying back. When conditions have improved, the plants would produce new tillers in the centre of the crown.

Importance of Perennial ryegrass (*Lolium perenne*)

Perennial ryegrass is highly palatable, nutritious and has an excellent animal production potential. It will provide grazing for about 10 to 11 months of the year and will be dormant in the dry months (Dannhauser, 1991). Perennial ryegrass can withstand close continuous grazing and is ideally suited to intensive sheep and cattle grazing.

2.6.2 Annual ryegrass (*Lolium multiflorum*)

Annual ryegrass (*Lolium multiflorum*) is a high quality, cool season winter annual grass that is closely related to perennial ryegrass (*Lolium perenne*), the *Lolium* and *Festuca* genera are classified within the family *Poaceae* (Wheeler *et al*., 2002). Annual ryegrass is divided into two distinct cultivar groups: (1) Italian ryegrass, which requires an extended period of low temperatures to flower prolifically and (2) Westerwolds ryegrass, which has no cold inductive requirement for flowering and will go into a reproductive phase in warm areas.

Annual ryegrass is a cool season annual or biennial turf forming bunch grass, but cultivars that may persist for more than two years have been developed. Leaf blades are dark green, hairless and the upper surface is ribbed, while the lower surface is smooth and shiny. Leaf blades are up to 40 cm long and 5 -12 mm wide. Young leaves are rolled in the bud. Auricles are small and narrow. Ligules are white, translucent and short. Leaf sheaths are hairless with fine longitudinal ribs, as in leaf blades (Lamp *et al*., 2001).

Establishment

Annual ryegrass is characterized by rapid germination under various environmental conditions. Annual rye grass is adaptable to a wide range of soil types and success can be achieved on very poor shallow soils provided the irrigation system and fertilization is highly effective (Fair, 1989). Ryegrass can be planted in autumn (February - April) and also in spring (August - Sep). The seeding rate is 10 - 20 kg/ha. It requires a high fertilization program (Dannhauser, 1991). The only problem with autumn planting is that seedlings suffer from "burn-off" in hot weather and can die if planted too early. Daily light irrigation can do a lot to overcome this problem (Fair, 1989).

Establishment limitations

Annual ryegrass is an expensive pasture which needs to be re-established each year. According to Dannhauser (1991), it has a shallow root system and high moisture requirement.

Nutrient requirements

Annual ryegrass requires a highly fertile soil to perform well and responds well to applications of nitrogenous fertilizers (Lamp *et al*., 2001). It has a wide range of soil adaptability and is being tolerant to acidic and alkaline soils (pH 5.0 to 7.8). Below a pH of 5.0, aluminium toxicity may be a problem and higher pH can cause chlorosis due to iron and manganese deficiencies. The best growth occurs when soil pH is maintained between 5.5 and 7.5 (Hanaway *et al*., 1999). It performs poorly unless it is heavily fertilized with nitrogen (Fair, 1989).

Temperature requirements and tolerances

Its growing season is autumn, winter and spring. It is particularly valued for its winter growth which is higher than perennial ryegrass (Lamp *et al*., 2001). It was found to have the fastest primary (uncut) growth during establishment and a broader tolerance to temperature than perennial ryegrass (Hill *et al*., 1985). It can be cultivated under dry land conditions, providing the rainfall exceeds 900 mm during the growing season (Dickinson *et al*., 1990). Annual rye grass is cultivated under irrigation in large parts of South Africa or as a winter and spring fodder. From results under irrigation at Potchefstroom, it appeared as if some cultivars stay vegetative for longer periods in spring and early summer than other cultivars (Dannhauser, 1991).

Importance of Annual ryegrass (*Lolium multiflorum*)

Italian ryegrass (annual or short-lived perennial), is used for forage and turf purposes throughout the temperate regions of the world, including North and South America, South Africa, Australia and New Zealand (Lamp *et al*., 2001). Due to its ability to establish quickly and grow rapidly in its first year, annual ryegrass is often included in permanent pasture mixtures to provide feed for the first winter after establishment. The grass is ideal for dairy or sheep farming in high rainfall or irrigation areas. Annual ryegrass, with its more upright and open growth habit is suited to grazing systems with lengthy intervals between grazing, or for silage production (Jung *et al*., 1996)

2.6.3 Cocksfoot (*Dactylis glomerata*)

Cocksfoot (*Dactylis glomerata*) is a cool season tussock-forming perennial grass which grows up to 1.5 m high, with strongly flattened vegetative shoots. It has a greyish-green to green foliage and the leaves are long (up to 80 cm) usually flat but may be folded lengthwise to give a shallow V-shaped cross-section. Translucent ligules are white with 2 - 10 mm long. Leaf sheaths are flattened and hairless (Lamp *et al*., 2001).

Establishment

Cocksfoot possesses a small, very light seed, averaging about 1.3 million/kg. It needs to be sown close to the soil surface at a depth of 10 mm or less. The suggested seeding rate is 10 - 15 kg/ha when sown in rows and when broadcasted with irrigation, 20 - 25 kg/ha. Cocksfoot is best sown in autumn. Early growth is slow, although it is generally more vigorous than tall fescue (Donaldson, 2001).

Establishment limitations

Early planting will pose a problem if seedbeds are not weed-free but late planting in weed problem situations will be more successful. Dry land cultivation is restricted to areas with a rainfall in excess of 750 mm (Fair, 1989).

Nutrient requirements

Cocksfoot responds to increasing soil fertility. New sowings require fertilizer to promote early root development and enhance seedling vigour. Mature stands should have major deficiencies corrected on the basis of soil analysis. Cocksfoot, like all grasses, responds to nitrogen either via a companion legume or fertilizer application (Fair, 1989).

Temperature requirements and tolerances

Cocksfoot prefers well drained loam and clay soils. It is essentially a cool climate grass and is suited best to winter rainfall conditions. It will also grow well in cool high summer rainfall areas (750 mm and more), where the soils are moist in winter or under irrigation. It does not like very warm northern-western aspects or very cold low-lying areas (Donaldson, 2001).

Importance of Cocksfoot (Dactylis glomerata)

Cocksfoot is valued throughout the world for its better persistence, than perennial ryegrass on quick drying and moderately fertile soils. It is a palatable grass which is best adapted to cooler regions which have a good rainfall. In these regions it will grow well on a wide range of soils and have a good animal production potential. Cocksfoot does not contain any substances harmful to animals (Fair, 1989). Cocksfoot can be used as one of the alternative temperate perennial grasses that could improve the persistence and stress tolerance (Reed, 1996, Callow *et al*., 2003, Nie *et al*., 2008) of the temperate grass component within kikuyu systems. There is however, limited data available on the production potential and forage quality of the most recent cultivars of these species under irrigation in the summer rainfall areas of SA.

CHAPTER 3:

RESEARCH DESIGN AND METHODOLOGY

3.1 Experimental site

The study was carried out at the Hygrotech Seed Company's Experimental farm. The farm is in Dewagensdrift, which is situated approximately 40 km south east of Pretoria, along the R573 route to the KwaMhlanga and Moloto villages. The GPS coordinates of the experimental farm are 25˚29" S and 28˚36.8" E. The climate is characterised by low temperatures in winter (± 2°C) and warm summer days (25 - 30°C) and the rainfall ranges from 550 to 660 mm/annum. The experiments were conducted during the 2011/2012 and 2012/2013 growing seasons. The soil in this area is sandy loam of the Clovelly form (Soil Classification Workgroup, 1991).

3.1.1 Meteorology

The Hygrotech Seed Company's Experimental farm is characterized by cool winter and warm summer temperatures. The monthly average meteorological data for the 2011, 2012 and 2013 seasons of the area was taken from the Agricultural Research Council's weather station at Roodeplaat, which is approximately 15 km from Dewagensdrift, and is given in Table 3.1, Table 3.2 and Table 3.3.

Legend:

Element	Description	Unit
Tx	Daily Maximum Temperature	°C
Tn	Daily Minimum Temperature	°C
Rain	Total Rainfall	mm
Rs	Total Radiation	MJ/m^2
U2	Average Wind Speed	ms
RHx	Daily Maximum Relative Humidity	%
RHn	Daily Minimum Relative Humidity	%
ET0	Total Relative Evapotranspiration	mm

Table 3.1: The monthly average meteorological data for 2011 at the Roodeplaat Experimental site (ARC); (Source: ARC ISCW, Agromet Section, Private Bag X 79, Pretoria 0001)

Month	Period	Tx	Tn	Rain	Rs	U2	RHx	RHn	ET0
January	1 - 31	28.25	17.25	392.1	21.73	0.69	90.96	44.43	4.35
February	1 - 28	29.40	15.84	40.1	24.47	0.57	89.68	35.77	4.88
March	1 - 31	30.08	14.97	127.6	22.02	0.47	90.57	34.17	4.39
April	1 - 30	24.52	11.77	111.6	15.28	0.48	92.88	45.16	2.86
May	1 - 31	23.77	6.30	5.10	15.43	0.47	93.61	32.54	2.72
June	1 - 30	21.03	0.67	11.9	15.41	0.82	89.21	22.56	2.57
July	1 - 31	20.21	0.84	0.30	16.32	0.91	83.58	20.28	2.72
August	1 - 31	23.71	3.47	5.40	19.61	0.86	82.19	20.93	3.50
September	1 - 30	28.86	8.20	1.30	24.26	1.09	77.27	14.84	4.89
October	1 - 31	29.49	11.92	63.70	25.84	0.99	81.97	21.24	5.21
November	1 - 30	30.31	14.46	67.20	26.93	1.12	83.11	25.53	5.65
December	1 - 31	28.91	16.51	164.30	23.45	0.73	88.50	38.70	4.77
Annual	**365**			**990.6**					

According to meteorological data in Table 3.1, the total rainfall recorded from January to December 2011 was 990.6 mm. The highest rainfall of 392.1 mm was recorded in January while the lowest rainfall was recorded in July 2011. The good rainfall in March (127.6 mm) and April (111.6 mm) guaranteed rapid germination and early growth after establishment. The lowest rainfall during May to September could have influenced the total dry matter production, which will be discussed later in Chapter 4. The lowest temperatures were in June (0.67°C) and July (0.84°C) whereas the maximum temperatures were recorded in March (30.08°C) and November (30.31°C).

Legend:

Element	Description	Unit
Tx	Daily Maximum Temperature	°C
Tn	Daily Minimum Temperature	°C
Rain	Total Rainfall	mm
Rs	Total Radiation	MJ/m^2
U2	Average Wind Speed	ms
RHx	Daily Maximum Relative Humidity	%
RHn	Daily Minimum Relative Humidity	%
ET0	Total Relative Evapotranspiration	mm

Table 3.2: The monthly average meteorological data for 2012 at the Roodeplaat Experimental site (ARC); (Source: ARC ISCW, Agromet Section, Private Bag X 79, Pretoria 0001).

Month	Period	Tx	Tn	Rain	Rs	U2	RHx	RHn	ET0
January	1 - 31	30.67	16.78	64.30	26.59	0.92	88.35	33.04	5.46
February	1 - 29	31.26	16.83	104.10	24.93	0.52	89.05	31.70	5.07
March	1 - 31	29.94	14.12	81.00	22.94	0.78	88.27	28.04	4.69
April	1 - 30	26.26	8.88	6.50	21.28	0.66	90.12	27.23	3.95
May	1 - 31	26.23	6.09	0.90	18.53	0.46	86.40	19.59	3.35
June	1 - 30	21.73	1.67	0.20	15.94	0.72	85.25	21.56	2.70
July	1 - 31	22.89	2.75	0	17.27	0.86	81.26	18.49	3.00
August	1 - 31	25.09	4.86	0	18.63	1.06	73.86	15.89	3.55
September	1 - 30	26.16	8.95	74.30	22.42	1.42	82.09	25.78	4.41
October	1 - 31	27.75	12.13	108.70	23.65	1.15	86.81	33.63	4.67
November	1 - 30	29.42	13.57	81.20	26.91	0.95	87.32	30.53	5.39
December	1 - 31	28.67	16.13	154	26.10	0.77	89.47	38.42	5.17
Annual	**365**			**675.2**					

According to Table 3.2, the total annual rainfall for 2012 was 675.2 mm. Good rainfall was recorded in February and October with 104.1 mm and 108.7 mm, respectively. The poor rainfall that occurred from April to August 2012 might be the reason for the low dry matter production recorded in the season, to be discussed in Chapter 4. High temperatures were recorded in January (30.67°C) and February (31.26°C) while low temperatures were recorded in June (1.67°C) and July (2.75°C).

Legend:

Element	Description	Unit
Tx	Daily Maximum Temperature	°C
Tn	Daily Minimum Temperature	°C
Rain	Total Rainfall	mm
Rs	Total Radiation	MJ/m^2
U2	Average Wind Speed	ms
RHx	Daily Maximum Relative Humidity	%
RHn	Daily Minimum Relative Humidity	%
ET0	Total Relative Evapotranspiration	mm

Table 3.3: The monthly average meteorological data for 2013 at the Roodeplaat Experimental site (ARC); (Source: ARC ISCW, Agromet Section, Private Bag X 79, Pretoria 0001).

Month	Period	Tx	Tn	Rain	Rs	U2	RHx	RHn	ET0
January	1 - 31	30.73	16.85	90.30	26.29	0.90	87.45	34.61	5.42
February	1 - 28	32.06	15.77	35.00	26.53	0.81	88.80	27.89	5.51
March	1 - 31	29.53	14.43	75.90	21.31	0.75	89.78	30.54	4.30
April	1 - 30	26.10	9.21	98.20	19.30	0.67	91.70	32.39	3.59
May	1 - 31	24.83	4.97	0.55	17.44	0.59	89.73	23.43	3.07
June	1 - 30	23.31	2.20	0	16.20	0.74	88.94	21.04	2.83
July	1 - 31	22.44	3.04	0	16.09	0.77	85.45	22.49	2.80
August	1 - 31	22.96	2.90	0	18.39	0.90	80.35	19.17	3.26
September	1 - 30	-	-	6.6	-	-	-	-	-
October	1 - 31	-	-	103.63	-	-	-	-	-
November	1 - 30	-	-	87.62	-	-	-	-	-
December	1 - 31	-	-	186.17	-	-	-	-	-
Annual	**365**			**683.97**					

Table 3.3 shows that the total rainfall recorded for 2013 was 683.97 mm, which was higher than the total rainfall obtained in 2012; however it was lower than the total rainfall recorded in 2011. The rainfall was poor in May (0.55 mm), whereas from June to August no rainfall that was recorded, this could be a reason why data was not collected every month, to be discussed further in chapter 4. The lowest temperatures were recorded in June (2.20°C) and August (2.90°C)

3.2 Materials and methods

3.2.1 Land/site preparation

The site/land was ploughed and then worked with a disc harrow or rotavator to control weeds and loosen the soil. The final preparation was done with the tiller for fine seedbeds and to mechanically eradicate weeds.

3.2.2 Fertilization and irrigation

Before planting soil samples were taken to a depth of 0 - 200 mm top soil and 210 - 300 mm sub soil to be analyzed. The fertilizers applied were:

- Terra Nova (organic fertilizer made of chicken manure): 3.5% N; 1.35% P; 2.25% K; 4% Ca; 0.5% S + micro elements (Zn, Mn, Cu, Fe & B)
- MAP (11% N & 22%P)
- Potash Nitrate [KNO_3]: (13.5% N & 38.4% K)
- NPK Mixture: 3:1:5 (26)

The total rate of application is specified in Table 3.4

Table 3.4: Total fertilizers applied (kg/ha).

Source	Fertilization level (kg/ha)		
	Low	Medium	High
Terra Nova (before planting)	200 kg/ha	200 kg/ha	200 kg/ha
Terra Nova (after planting)	600 kg/ha	600 kg/ha	600 kg/ha
Top dressings			
MAP	250 kg/ha	250 kg/ha	250 kg/ha
KNO_3	100 kg/ha	100 kg/ha	100 kg/ha
3:1:5 (26)		645 kg/ha	860 kg/ha
LAN (28%)	250 kg/ha	250 kg/ha	522 kg/ha)

The time of application was as follows:

- Before planting: The equivalent of 200 kg/ha Terra Nova and disc in.
- After germination: The equivalent of 620 kg/ha Terra Nova
- Top dressings after cuts: Low application level: One application of MAP; KNO_3 & LAN. Medium level: One application of MAP and KNO_3; two applications of 3:1:5

(26) and one of LAN. <u>High level</u>: One application: MAP; and KNO_3 and two applications of 3:1:5 (26) and LAN

Seeds were planted in nine rows of 100 mm apart in the bigger plot of 1.5 m x 6.0 m (9 m^2). An irrigation schedule of 20 - 25 mm/week was applied depending on the climatic conditions, for the full growing period.

3.2.3 Experimental design and treatment details

Three different planting dates were applied (16 March 2011, 21 April 2011 and 4 April 2012). For each planting date, 51 plots of 6.0 m x 1.5 m (9 m^2) were arranged in a randomized complete block design, with three replications. Treatments involved were three planting dates with 17 cultivars. For all the cultivars that were planted, a seeding rate of 20 g per 9 m^2 (20 kg/ha) and a raw spacing of 100 mm apart (nine rows/plot) was used. Three fertilizer levels (low, medium and high) were applied in three sub-plots (split plots), 1 m x 1 m in size, on each of the plots. A soil analysis was used as guideline for the medium fertilizer level. The low and high fertilizers were adapted to test low and high fertilizer level treatments.

Table 3.5: The 14 cultivars and three mixtures that were evaluated during the study

***Festulolium* hybrids:** crosses between *Festuca spp* and *Lolium multiflorum* (annual ryegrass) or *Lolium perenne* (perennial ryegrass)				
Cultivar	Scientific name	Festuca parent	*Lolium* parent	Type
Achilles	*Festululium braunii*	*F. prantesis*	*L. multiflorum*	Italian
Becva	*Festulolium pabulare*	*F. arundinacea*	*L. multiflorum*	Italian
Fotjan	*Festulolium pabulare*	*F. arundinacea*	*L. multiflorum*	Tall fescue
Lofa	*Festulolium pabulare*	*F. arundinacea*	*L. multiflorum*	Perennial
Perseus	*Festululium braunii*	*F. prantesis*	*L. multiflorum*	Italian
Perun	*Festululium braunii*	*F. prantesis*	*L. multiflorum*	Italian

***Lolium* hybrids:** crosses between *Lolium multiflorum* (annual ryegrass) or *Lolium perenne* (perennial ryegrass)		
Cultivar	Species	Type
Citeliac	Perennial x Italian hybrid ryegrass	Perennial
Fotimo	Perennial x Italian hybrid ryegrass	Italian
Solid 4N	Perennial x Italian hybrid ryegrass	intermediate
Storm	Perennial x Italian hybrid ryegrass	Perennial
Tirna 4N	Perennial x Italian hybrid ryegrass	Italian

Grass-legume mixtures		
Cultivar	Contents	
CutMax Alfa Protein Hot & Dry	40% alfalfa + 15% hybrid ryegrass + 15% cocksfoot + 15 % tall fescue + 15 % Bromus enermis	
GrazeMax Hot & Dry	10% white clover + 70% tall fescue + 20% perennial ryegrass	
VersaMax Hot & Dry	10% red clover + 5% white clover + 40% hybrid ryegrass + 20% cocksfoot + 25% tall fescue	
Dactylis species		
Cultivar	Scientific name	Common name
Aramis	*Dactylis glomerata*	Cocksfoot
Niva	*Dactylis glomerata*	Cocksfoot
Porthos	*Dactylis glomerata*	Cocksfoot

3.2.4 Species and Mixtures used

Six different cutivars of *Festulolium hybrids*, five cultivars of *Lolium hybrids*, three cultivars of *Dactylis species* and three grass/legume mixtures were used and specified in Table 3.5.

3.3 Data collection

Plots were harvested on a monthly basis. Thereafter the samples were placed in brown bags, weighed for fresh/wet weight and then dried in a drying oven at 60ºC until they reached a constant dry weight. Dried samples were removed from the oven and weighed to determine the monthly, seasonal and total annual dry matter production.

3.4 Statistical analysis

Growth and yield data of the seventeen cultivars generated from the three different planting dates was subjected to analysis of variance (ANOVA) to assess the treatment effects as well as their interaction at 5 % significance ($P < 0.05$) using the statistical program Genstat® (Payne *et al*., 2012). Linear Mixed Model Repeated Measurements Analysis, also known as REML (Restricted Maximum Likelihood), was applied to cumulative yields (Payne, Welham and Harding, 2012). The fixed effects were specified as fertilizers, species, cultivars, planting dates and their interaction. Fischer's protected least significant difference (LSD) test was used to separate means at the 5 % level (Payne *et al*., 2012).

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Soil analysis

Prior to establishment of the experiments soil samples were taken and analyzed. The results are given in Table 4.1.

Table 4.1: **Soil analysis results from the experimental site at Dewageningsdrift (Hygrotech Seed Company's Experimental Farm)**

Soil depth	H_20	Bray 1	Ammonium Acetate Extractable				
	pH	P (mg/kg)	Ca (mg/kg)	K (mg/kg)	Mg (mg/kg)	Na (mg/kg)	C (%)
Top (0 – 200 mm)	6.1	48.2	211	66	45	12	0.26
Sub (210 – 300 mm)	5.7	24.2	123	24	24	-2.4	0.25

4.1.1 The pH

To achieve the best production with *Festulolium* hybrids, *Lolium species*, grass-legume mixtures and *Dactylis glomerata* cultivars, a pH range of 5.0 to 8.0 is recommended (Lampel *et al*., 2001 and Cool and Annaway, 2004). The availability of macro-elements (Ca, K, Mg, Na and S) as well as most of the micro-nutrients is directly influenced by soil pH (Donaldson, 2001). Most grasses tend not to be sensitive to soil pH. However, evidence shows that in high rainfall areas, low pH will certainly influence production of grass. Table 4.1 shows that the pH value ranged between 5.7 and 6.1 (subsoil and topsoil, respectively). This fell within the recommended range for these species.

4.1.2 Phosphate (P)

Major P deficiencies may not be rectified after establishment and soil analysis prior to planting is therefore crucial. According to Table 4.1, the P value ranged between 48.2 and 24.2 mg/kg (topsoil and subsoil, respectively) which was much higher than the recommended P value of 25 mg/kg required under high rainfall and irrigation conditions (Dannhauser, 2001). For this reason only a minimum top dressing of P was applied as indicated in Chapter 3, Paragraph 3.2.2.

4.2 Dry Matter (DM) production

The DM production on the different treatments was cut, collected, dried and weighed as described in Paragraph 3.3, in Chapter 3. The results were collected and statistically analysed in different growing seasons (phases) for each planting date as indicated in Table 4.2. The cutting frequency throughout the experiment was on an approximate monthly basis while growth occurred.

Take note that the mixtures (Cutmax Alfa, Grazemax and Versamax) were grouped as for the grass species for statistical analysis.

Table 4.2: The division of the monthly regrowth in production seasons (phases) for the three planting dates.

No	Planting date	Phase	Growing Season	Starting date	End date
1	16 March 2011	1	Mid-summer	06/09/2011	11/06/2012
		2	Mid-winter	05/12/2011	01/11/2012
2	21 April 2011	1	Mid-summer	28/09/2011	11/06/2012
		2	Mid-winter	16/01/2012	04/12/2012
		3	Mid-summer	11/06/2012	29/05/2013
3	04 April 2012	1	Mid-summer	11/06/2012	29/05/2013

The results obtained in the different phases at the different planting dates were compared in the following different combinations:

- The effect of different fertilization levels on the DM production of all cultivars and mixtures during Phase 1 (mid-summer) of Planting date 1 (16 March 2011) (Paragraph 4.2.1)
- Evaluation of DM production during all the three phases (first mid-summer, first mid-winter and second mid-summer) of the second Planting date (21 April 2011) (Paragraph 4.2.2)
- The effect of the three planting dates at medium fertilization on the DM production during the first phase (mid-summer) of each planting date (Paragraph 4.2.3)
- The influence of planting dates (16 March 2011 and 21 April 2011) on the DM production of Phase 2 (mid-winter) (Paragraph 4.2.4)

4.2.1 The effect of different fertilization levels on the dry matter production of all cultivars and mixtures during Phase 1 (mid-summer) of Planting date 1 (16 March 2011).

Table 4.3: The planting date and phase, marked green, was used in this division for the discussion in Paragraph 4.2.1

No	Planting date	Phase	Growing	Starting date	End date
1	16 March 2011	1	Mid-summer	06/09/2011	11/06/2012
		2	Mid-winter	05/12/2011	01/11/2012
2	21 April 2011	1	Mid-summer	28/09/2011	11/06/2012
		2	Mid-winter	16/01/2012	04/12/2012
		3	Mid-summer	11/06/2012	29/05/2013
3	04 April 2012	1	Mid-summer	11/06/2012	29/05/2013

The fertilization frequency and levels applied are shown in Paragraph 3.2.2 in Chapter 3. The total fertiliser applied during the first phase of Planting date 1 (16^{th} March 2011) is indicated in Table 4.4.

Table 4.4: **Fertilization levels (kg N+P+K/ha) during Phase 1 (mid-summer) of planting date 1 (16 March 2011)**

Fertilizer level	Total kg N+P+K/ha (06/09/2011 to 11/06/2012)		
	Nitrogen (kg N/ha)	Phosphorus (kg P/ha)	Potassium (kg K/ha)
1 (Low)	139	66	56
2 (Medium)	195	85	149
3 (High)	262	91	180

According to the statistical analysis (Addendum 1.1) the fertilizer levels (as main effect) had a highly significant influence (P = 0.008) on DM production, which is shown in Figure 4.1.

According to results in Figure 4.1, the low fertilizer level resulted in significantly (P = 0.008), low DM production (8.36 t/ha), while no significant difference occurred between DM production of the medium and high fertilization levels (10.93 t/ha and 11.92 t/ha, respectively).

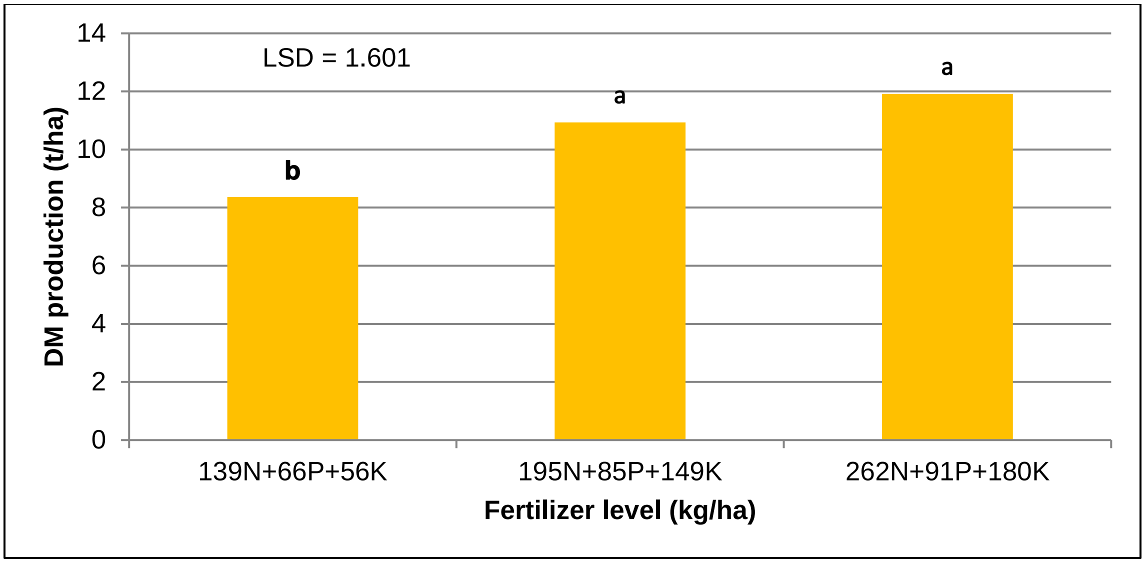

Figure 4.1: **The average DM production at different fertilizer levels**

According to Table 4.5, the DM production of species as main effect (average of cultivars) and mixtures did not differ significantly and varied between 9.39 t/ha and 10.88 t/ha. The average DM productions of *Dactylis species* and of mixtures were lower than 10 t/ha. The interaction between species and level of fertilization was not significant (P = 1.00). However when compared with a Fischer's protected LSD of 2.588 (Table 4.5) three different production groups were identified. The low fertilizer level resulted in the lowest DM production of all the species (green blocks in the table).

Table 4.5: The influence of the interaction between fertilization level and species on average DM production in Phase 1 Planting date 1 (16 March 2011)

Fertilization (kg/ha)	Species (t/ha)				Average Fertilization
	Festulolium	*Dactylis*	*Lolium*	Mixtures	
139N+66P+56K	8.78	7.24	8.93	7.73	8.36^{b}
195N+85P+149K	11.33	10.12	11.33	10.28	10.93^{a}
262N+91P+180K	12.53	10.82	12.23	11.25	11.91^{a}
Average (Sp)	10.88^{a}	9.39^{a}	10.83^{a}	9.76^{a}	
LSD (5%)					
Interaction	2.588				
Fertilizer	1.601				
Species	1.479				

The highest DM production was measured in the case of *Festulolium* hybrids and *Lolium* hybrids at the high fertilization level. The rest of the treatment formed an intermediate production group marked orange in the table (10.12 – 11.33 t/ha). According to Addendum 1.1.1, fertilizer level, as well as cultivars, influenced DM production significantly (P = 0.008 and P = 0.003 respectively). The influence of fertilization level (as main effect) was discussed in Figure 4.1, while the results of individual cultivars during, Phase 1 planted on the 16th March 2011, are shown in Table 4.6.

Table 4.6: The average DM production of cultivars during Phase 1 planted on the 16th of March 2011

Cultivars			Average DM (t/ha)
No	Name		
3	Fotjan	(*Festulolium*)	12.99 a
15	Cutmax alfa`	(Mixture)	12.12 ab
9	Porthos	(*Dactylis sp.*)	11.30 abc
10	Citeliac	(*Lolium sp.*)	11.24 abcd
5	Perseus	(*Festulolium*)	11.23 abcd
12	Solid 4N	(*Lolium sp.*)	11.21 abcd
6	Perun	(*Festulolium*)	10.71 bcde
7	Aramis	(*Dactylis sp.*)	10.64 bcdef
16	Grazemax	(Mixture)	10.59 bcdef
13	Storm	(*Lolium sp.*)	10.32 bcdef
14	Tirna 4N	(*Lolium sp.*)	10.22 bcdef
1	Achilles	(*Festulolium*)	9.70 cdef
8	Niva	(*Dactylis sp.*)	9.69 cdef
17	Versamax	(Mixture)	9.45 cdef
4	Lofa	(*Festulolium*)	9.08 def
2	Becva	(*Festulolium*)	8.59 ef
11	Fotimo	(*Lolium sp.*)	8.52 f
LSD (5%)			2.164

When comparing the results in Table 4.6 with a Fischer's protected LSD of 2.164, four different production groups occurred, marked in different colours in the table. The highest producers (red) were Fotjan (12.99 t/ha) and Cutmax Alfa (12.12 t/ha). The second highest production group (orange) produced between (11.21 t/ha and 11.30 t/ha). A third production group (light green) with production values of 10.22 t/ha and 10.71 t/ha occurred, while the lowest group (yellow) produced 9.70 t/ha and lower.

Table 4.7: The interaction between fertilization level and cultivars on average DM production in Phase 1 of Planting date 1 (16 March 2011)

Species	Cultivars	DM production (t/ha)		
		Low (139N+66P+56K)	Medium (195N+85P+149K)	High (262N+91P+180K)
Festulolium Hybrids	Achilles	7.209	10.756	11.134
	Becva	6.218	10.373	9.181
	Fotjan	9.935	13.945	15.094
	Lofa	7.452	8.928	10.847
	Perseus	9.075	12.031	12.573
	Perun	9.328	10.950	11.844
Dactylis species	Aramis	8.137	10.739	13.052
	Niva	7.752	10.359	10.971
	Porthos	10.071	11.762	12.072
Lolium hybrids	Citeliac	9.667	10.628	13.416
	Fotimo	6.058	9.249	10.248
	Solid 4N	8.405	11.566	13.668
	Storm	8.326	11.762	10.859
	Tirna 4N	7.696	11.655	11.297
Grass-legume mixtures	Cutmax Alfa	11.495	11.541	13.324
	Grazemax	8.201	12.190	11.376
	Versamax	7.177	9.569	11.602
Average (Fertilizer)		8.365[b]	10.933[a]	11.915[a]
LSD (5%) Interaction		3.813		

Although there was no significant interaction (P = 0.999) between fertilizer level and cultivars, three production groups could be identified when comparing production values (LSD 3.813; Addendum 1.1.1). These results are shown in Table 4.7 and marked in different colours and were also illustrated in Figure 4.2. The high producing group (11.282 t/ha to 15.094 t/ha) is marked red in Table 4.7 and occurred mainly in the medium and high fertilized treatments. Cutmax Alfa is a mixture including lucerne and was also in this group under the low fertilization treatment. The medium producing group (orange) included the medium and high fertilized treatments with productions of 9.871 t/ha to 11.281 t/ha. The low producing group (light green) produced less than 9.871 t/ha and included most cultivars at the low fertilization treatment. The *Festulolium* hybrid cultivar Becva was an exception with 9.181 t/ha at the high fertilization treatment.

4.2.1.1 Summary

The highest producers in Phase 1 (Mid-summer) of the 16th March 2011 planting date, as influenced by fertilization, are summarized in Table 4.8.

Table 4.8: **Summary of the highest DM production of cultivars under different fertilization levels during Phase 1 of Planting date 1 (16 March 2011)**

Species	Total DM production (t/ha)		
	Low Fertilization	Medium Fertilization	High Fertilization
Festulolium	Fotjan (9.935 t/ha)	Fotjan (13.945 t/ha)	Fotjan (15.094 t/ha)
Dactylis spp.	Porthos (10.071 t/ha)	Porthos (11.762 t/ha)	Aramis (13.052 t/ha)
Lolium	Citeliac (9.667 t/ha)	Storm (11.762 t/ha)	Solid 4N (13.668 t/ha) and Citeliac (13.416 t/ha)
Mixtures	Cutmax Alfa (11.495 t/ha)	Grazemax (12.190 t/ha)	Cutmax Alfa (13.324 t/ha)
Highest DM production	Cutmax Alfa (11.495 t/ha)	Fotjan (13.9 t/ha)	Fotjan (15.094 t/ha)

From the results and discussions it is clear that the low fertilization level resulted in the lowest DM production of *Festulolium* hybrids, *Dactylis species*, *Lolium* hybrids and grass-legume mixtures cultivars. No significant differences occurred between the medium and high fertilization level. Species, as a main effect was not influenced by fertilization. The highest DM production occurred with *Festulolium* hybrids and *Lolium* hybrids at both medium and high fertilization levels, as well as grass-legume mixtures at the high fertilizer level. The highest producing cultivar was Fotjan at both the medium and high fertilization levels, while Cutmax Alfa performed best at the low fertilization level.

Marais (2001) mentioned that DM yield of pasture species is influenced by genetic factors, such as grass species and variety, and also environmental factors, such as soil type, fertilization level, and grazing or cutting management. High fertilization is not always economic, thus fertilization of temperate winter fodder species can be one of the critical and cost-effective elements in the production of animal feed and in fodder flow planning.

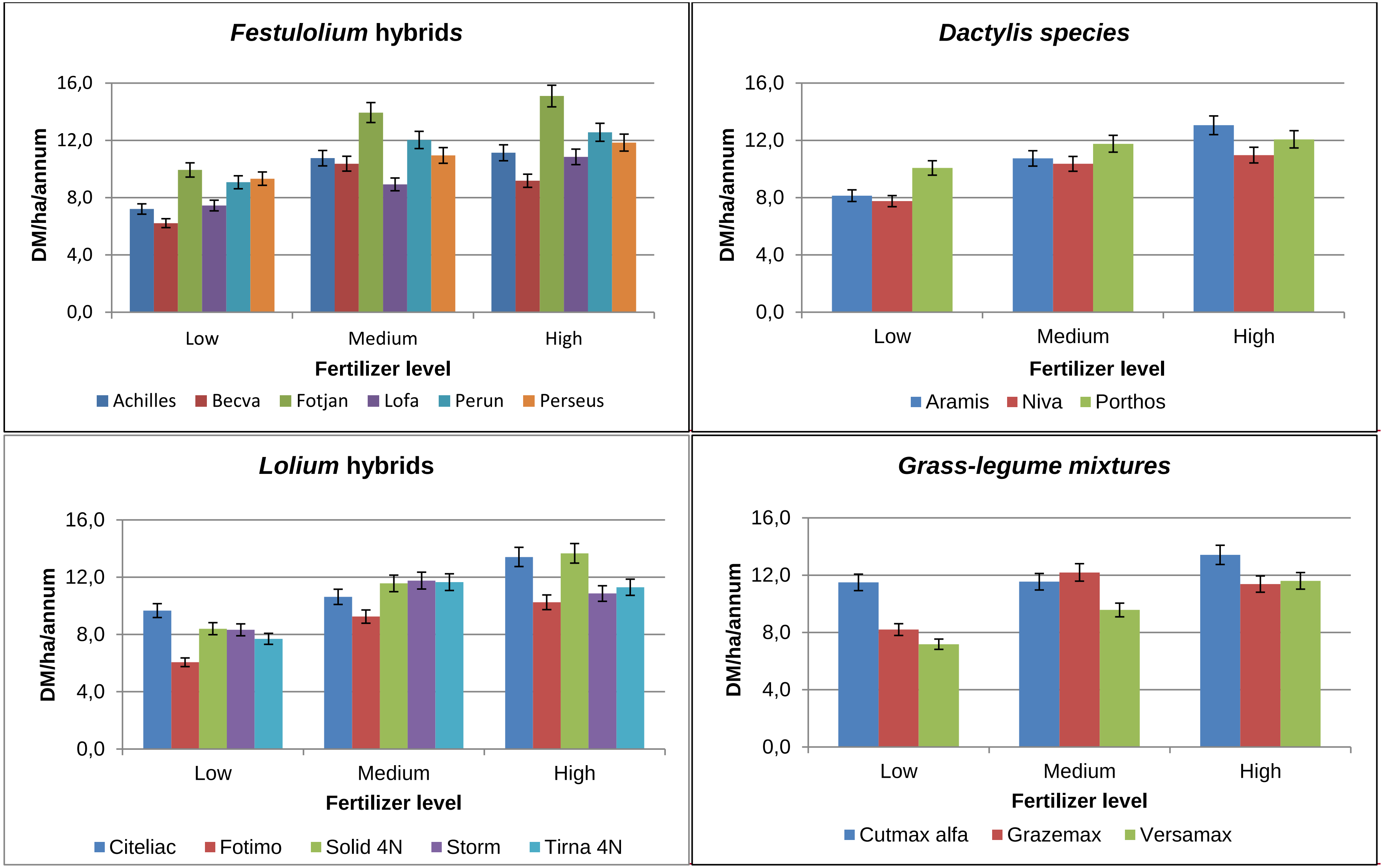

Figure 4.2: Effect of low, medium and high fertilizer levels on DM production of *Festulolium* hybrids, *Dactylis species*, *Lolium* hybrids and grass-legume mixtures cultivars during Phase 1 of PD 1 (16 March 2011)

4.2.2 Evaluation of DM production during all three phases (first mid-summer, mid-winter and second mid-summer) of the second planting date (21st April 2011)

Table 4.9: The planting date and different phases, marked green, were used in this division for the discussion in Paragraph 4.2.2

No	Planting date	Phase	Growing	Starting date	End date
1	16 March 2011	1	Mid-summer	06/09/2011	11/06/2012
		2	Mid-winter	05/12/2011	01/11/2012
2	21 April 2011	1	Mid-summer	28/09/2011	11/06/2012
		2	Mid-winter	16/01/2012	04/12/2012
		3	Mid-summer	11/06/2012	29/05/2013
3	04 April 2012	1	Mid-summer	11/06/2012	29/05/2013

The aim of this division was to evaluate the production and survival of all cultivars over two seasons (20 months).

4.2.2.1 The DM production of the *Festulolium* hybrids, *Dactylis species*, *Lolium* hybrids (average DM production of cultivars) and mixtures during the three phases (seasons) of Planting date 2 (21 April 2011)

The DM production of species/mixtures as main effect, in all three phases, is shown in Table 4.10. The interaction between species/mixtures and seasons was not statistically analyzed. The average DM production of species (as main effect) was analyzed separately for each phase and shown in Addendum 2.1 (Phase 1), 2.2 (Phase 2) and 2.3 (Phase 3). Please note that each production phase has its own LSD.

Table 4.10: The influence of the seasons and species on average DM production at Planting date 2 (21 April 2011)

Phases	Seasons	Species (t/ha)				Mean (t/ha)	LSD (5%)
		Festulolium	*Dactylis*	*Lolium*	Mixtures		
1	1st Mid-summer	13.737[a]	12.891[a]	14.268[a]	16.066[a]	14.240	3.423
2	Mid-winter	11.726[b]	12.044[b]	11.067[b]	13.955[a]	12.198	1.600
3	2nd Mid-summer	14.760[b]	15.107[ab]	14.439[b]	16.530[a]	15.209	1.679
Average for species		13.408	13.347	13.258	15.517		

According to Addendum 2.1 there was no significant difference in DM production between species (as main effect) (P = 0.228) in Phase 1. During Phase 2 the DM production differed significantly between species (P = 0.014) (Addendum 2.2). During Phase 3 differences between DM productions seemed not to differ significantly (P = 0.063), although when comparing with a Fisher's protected LSD of 1.679 significant differences occurred.

During Phase 1 there was no significant difference in DM production between the three species and mixtures. During Phase 2 mixtures produced the highest (13.955 t/ha) that was significantly higher than the three species (11.067 – 12.044 t/ha). During Phase 3 three production groups were identified: Mixtures with 16.530 t/ha, *Dactylis* cultivars with 15.107 t/ha and the other two species with 14.439 and 14.76 t/ha.

4.2.2.2 The DM production (t/ha) of the different cultivars during all three phases (seasons) at Planting date 2 (21 April 2011)

Addendum 2.1.1 indicates that the DM production of cultivars (as main effect) did not differ significantly (P = 0.064) in Phase 1 (mid-summer). According to Addendum 2.2.1 and 2.3.1, the DM production of cultivars differed significantly during Phase 2 (Mid-winter) and Phase 3 (mid-summer) (P = 0.001 and P = 0.035, respectively). The DM productions of cultivars as main effect, in all three phases, is shown in Table 4.11 and illustrated more visually in Figure 4.3. The interactions between cultivars and species were not statistically analyzed.

Although there was no significant difference (P = 0.064) between the DM productions of different cultivars in Phase 1, four different production groups were identified when comparing data with a Fischer's protected LSD of 4.645:

- High producer (Red): Cutmax Alfa with 20.943 t/ha
- Medium high producers (Orange): between 15 and 16 t/ha: Grazemax and Tirna 4N
- Medium low producers (Light green): between 12.59 and 14.9 t/ha: included twelve of the cultivars that were not in the other three groups

➢ Low producers (Yellow): Versamax (11.291 t/ha) and Becva (11.134 t/ha)

Table 4.11: The DM production (t/ha) of cultivars during the three different phases (seasons) planted on Planting date 2 (21 April 2011)

Phase 1 1st Mid-summer Add. 2.1.1			Phase 2 Mid-winter Add. 2.2.1			Phase 3 2nd Mid-summer Add 2.3.1		
Cutmax Alfa	20.943	a	Cutmax Alfa	16.336	a	Fotjan	18.697	a
Grazemax	15.963	b	Fotjan	15.128	a	Grazemax	18.346	ab
Tirna 4N	15.831	b	Grazemax	14.720	ab	Aramis	17.025	abc
Achilles	14.880	bc	Perun	12.554	bc	Cutmax Alfa	16.732	abc
Solid 4N	14.820	bc	Aramis	12.399	c	Perun	16.651	abc
Lofa	14.279	bc	Porthos	12.125	c	Solid 4N	16.446	abc
Perun	14.241	bc	Fotimo	11.973	c	Fotimo	15.094	abcd
Perseus	14.230	bc	Solid 4N	11.804	c	Perseus	14.962	abcd
Storm	14.090	bc	Perseus	11.782	c	Porthos	14.918	abcd
Fotimo	13.909	bc	Niva	11.607	c	Lofa	14.677	abcd
Fotjan	13.657	bc	Lofa	11.229	c	Versamax	14.512	bcd
Niva	13.246	bc	Versamax	10.809	cd	Storm	13.900	cd
Porthos	12.837	bc	Achilles	10.703	cd	Tirna 4N	13.749	cd
Citaliac	12.686	bc	Citeliac	10.621	cd	Niva	13.379	cd
Aramis	12.590	bc	Tirna 4N	10.494	cd	Citeliac	13.007	cd
Versamax	11.291	c	Storm	10.442	cd	Becva	12.189	d
Becva	11.134	c	Becva	8.962	d	Achilles	11.382	d
Mean	**14.155**		**Mean**	**11.982**		**Mean**	**15.209**	
LSD	**4.645**		**LSD**	**2.213**		**LSD**	**4.064**	

According to Addendum 2.2.1, the DM production of cultivars in Phase 2 differed significantly (P = 0.001) from each other. The DM production varied between 8.961 t/ha to 16.336 t/ha with Becva being the lowest producer, while Cutmax Alfa produced the highest. Comparing the data with a Fischer's protected LSD of 2.213; five different production groups were identified:

➢ High producers (Red): more than 15 t/ha : Cutmax Alfa and Fotjan

➢ Medium high producers (Orange): Grazemax (14.72 t/ha) and Perun (12.55 t/ha)

➢ Medium producers (Light green): between 11.229 and 12.399 t/ha: Aramis, Porthos, Solid 4N, Perseus, Niva and Lofa

- Medium low producers (Dark green): between 10.442 and 10.809 t/ha: Versamax, Achilles, Citeliac, Tirna 4N and Storm
- Low producers (Yellow): Becva (8.962 t/ha)

According to Addendum 2.3.1, the DM production of cultivars in Phase 3 differed significantly (P = 0.035) from each other, with values that ranged between 11.382 and 18.697 t/ha. Comparing the data with a Fischer's protected LSD of 4.064; five different production groups were identified:

- High producers (Red): more than 18 t/ha: Fotjan and Grazemax
- Medium high producers (Orange): between 16.446 and 17.025 t/ha: Aramis, Cutmax Alfa, Perun and Solid 4N
- Medium producers (Light green): between 14.512 and 15.094 t/ha: and Fotimo, Perseus, Porthos, Lofa and Versamax
- Medium low producers (Dark green): between 13 and 13.9 t/ha: Storm, Tirna 4N, Niva and Citeliac
- Low producers (Yellow): Becva (12.189 t/ha) and Achilles (11.382 t/ha)

4.2.2.3 <u>Summary</u>

According to Table 4.11 and Figure 4.3, cultivars responded differently during the three phases (seasons). On average, the grass-legume mixture Cutmax Alfa had the highest DM production in Phases 1 and 2, while Fotjan (*Festulolium* hybrid) produced the highest in Phase 3. Cultivar Fotjan produced low during Phase 1 and might be defined as a slow starter. The grass-legume mixture Grazemax was during all three phases a high producers (above 14.5 t/ha), while Versamax was a relative low producer in all three phases. Aramis (*Festulolium* hybrid). Perun and Solid were all three "slow starters" but produced more than 16 t/ha in Phase 3. *Lolium perenne* (cv. Tirna 4N) was in the high producing group in Phase 1, but production declined after that.

The continuous growth curves of the different grass cultivars (mixtures not included), given in Figure 4.4 are based on individual cuts from September 2011 to May 2013. Some cultivars maintained their production fluctuations from September 2011 to May 2013.

Most grass cultivars produced above 2.5 t/ha/cut in the second and third cuts (October and November 2011), except Becva and Perun (both *Festulolium* hybrids). During the following autumn and winter (February to July 2012) the production per cut of all cultivars declined to below 1.5 t/ha, except Perseus en Perun (both *Festulolium* hybrids). From August 2012 to February 2013 (second spring and summer), all cultivars showed, in general, an increase in production and after that a decrease in the second winter.

According to Figure 4.4, the results showed much fluctuation but the following nine cultivars need special notification for the following reasons:

- Becva, Perseus, Perun (*Festulolium* hybrids), Niva (*Dactylis spp*): They were the cultivars with the most constant production over the full period (between 1.3 and 1.5 t/ha/cut). Niva and Perun showed an increase in production towards the second winter, while Perseus showed a high production during the first summer.
- Aramis (*Dactylis spp*): The production of Aramis showed fluctuation over the full period, but showed an increase in production towards the second winter that made it one of the best producers in Phase 3.
- Fotjan (*Festulolium* hybrid): According to Table 4.10 a high producer in general, but a low producer in winter.
- Lofa (*Festulolium* hybrid), Tirna 4N and Fotimo (both *Lolium* hybrids): All average producers, but with a clear increase in production towards the second winter. The last two mentioned cultivars were both high summer producers.

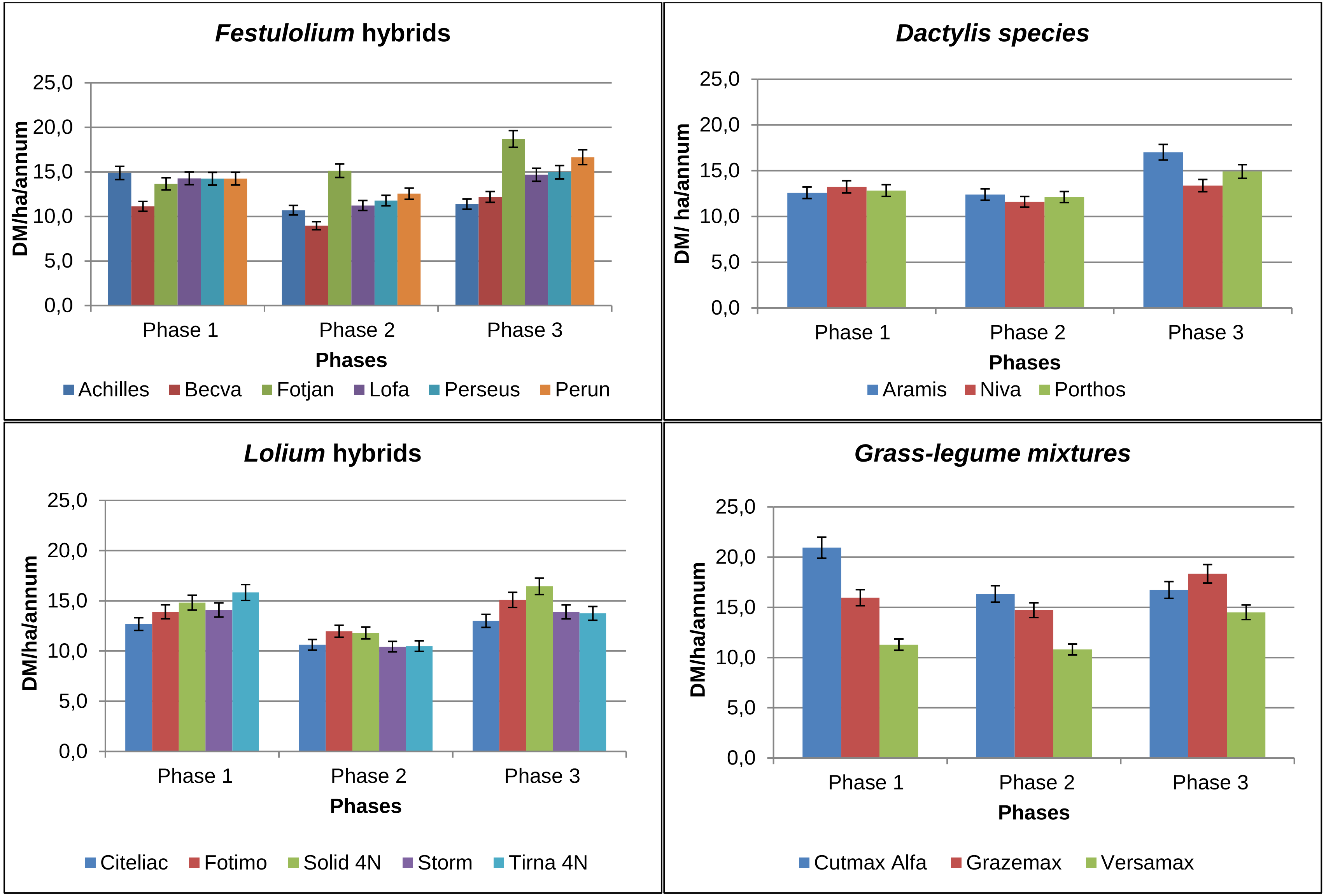

Figure 4.3: **The DM production (t/ha) of cultivars during the three different phases (seasons) at Planting date 2 (21 April 2011).**

4.2.3 The effect of the three planting dates at medium fertilization on the DM production during the first phase (mid-summer) of each planting date

Table 4.12: The different planting dates and different phases, marked green, were used in this division for the discussion in Paragraph 4.2.3

No	Planting date	Phase	Growing	Starting date	End date
1	16 March 2011	1	Mid-summer	06/09/2011	11/06/2012
		2	Mid-winter	05/12/2011	01/11/2012
2	21 April 2011	1	Mid-summer	28/09/2011	11/06/2012
		2	Mid-winter	16/01/2012	04/12/2012
		3	Mid-summer	11/06/2012	29/05/2013
3	04 April 2012	1	Mid-summer	11/06/2012	29/05/2013

The aim of using these results in this division was to investigate the influence of early and late planting dates on establishment success.

4.2.3.1 The influence of planting dates on the DM production of the *Festulolium* hybrids, *Dactylis species*, *Lolium* hybrids (average DM production of cultivars) and mixtures

According to Addendum 1.1, 2.1 and 3.1 the DM production of species and mixtures did not differ significantly between PD 1, PD 2 and PD 3 (P = 0.060, P = 0.228 and P = 0.871, respectively).

Table 4.13: The DM production (t/ha) of species as main effect during Phase 1 (mid-summer) of all three planting dates

Planting dates	Species				LSD (5 %)	From Add.
	Festulolium	*Dactylis*	*Lolium*	Mixtures		
PD 1	11.330a	10.122a	11.334a	10.284a	1.601	1.1
PD 2	13.737a	12.891a	14.268a	16.066a	3.423	2.1
PD 3	15.008a	14.750a	13.906a	14.124a	4.379	3.1

When comparing the results horizontally with Fischer's protected LSD of 1.601, 3.423 and 4.379 for PD 1, 2 and 3, respectively, no significant differences were visible for PD 1, PD 2 and PD 3. According to Table 4.13, the DM production of *Festulolium* hybrids and *Dactylis spp*. increased progressively from PD 1 to PD 3. In the case of *Lolium* hybrids and mixtures the highest DM production occurred when planted during late April 2011(PD 2)

The differences between DM productions for cultivars were analyzed separately for the three planting dates and the statistical analyses are given in Addendum 1.1.1, 2.1.1 and 3.1.1, respectively. The analysis showed a significant difference (P = 0.003) between the DM productions of cultivars at PD 1. At PD 2 and PD 3 the DM production of cultivars did not differ significantly (P = 0.064 and P = 0.251).

Table 4.14: The DM production (t/ha) of cultivars as main effect during Phase 1 (mid-summer) on three different planting dates

PD 1 (16/3/2011) Add. 1.1.1			PD 2 (21/4/2011) Add. 2.1.1			PD 3 (4/4/2012) Add. 3.1.1		
Fotjan	13.94	a	Cutmax Alfa	20.94	a	-	-	-
Grazemax	12.19	ab	Grazemax	15.96	ab	Porthos	18.50	a
Perseus	12.03	ab	Tirna 4N	15.83	ab	Grazemax	17.16	a
Porthos	11.76	b	Achilles	14.88	bc	Cutmax	16.67	ab
Storm	11.76	b	Solid 4N	14.82	bc	Solid 4N	16.49	ab
Tirna 4N	11.65	b	Lofa	14.28	bc	-	-	-
Solid 4N	11.57	b	Perun	14.24	bc	Lofa	16.44	ab
Cutmax Alfa	11.54	b	Perseus	14.23	bc	Becva	16.21	ab
Perun	10.95	bc	Storm	14.09	bc	Fotjan	15.04	abc
Achilles	10.76	bc	Fotimo	13.91	bc	Tirna 4N	14.59	abc
Aramis	10.73	bc	Fotjan	13.66	bc	Fotimo	14.35	abc
Citeliac	10.73	bc	Niva	13.25	bc	Citeliac	14.11	abc
Becva	10.37	bc	Porthos	12.84	bc	Niva	12.89	abc
Niva	10.36	bc	Citeliac	12.69	bc	Aramis	12.84	abc
Versamax	9.57	c	Aramis	12.55	bc	Perseus	12.34	abc
Fotimo	9.25	c	Versamax	11.29	c	Storm	9.99	bc
Lofa	8.93	c	Becva	11.13	c	Versamax	8.56	c
Mean	10.405		Mean	14.240		Mean	14.413	
LSD	2.164		LSD	4.645		LSD	6.859	

When comparing the DM production results of cultivars, for each planting date, with different Fischer's LSD's, there was a trend of a significant difference. The different DM production groups are indicated with different colours in Table 4.14 and more visually in Figure 4.5.

When comparing the DM production results of the different cultivars in Table 4.14 with LSD's of 2.164 for PD 1, 4.645 for PD 2 and 6.859 for PD 3, the following conclusions can be made:

For PD 1, five different production groups were identified:

- High producers (Red): Fotjan with 13.94 t/ha (*Festulolium* hybrid cv.)
- Medium high producers (Orange): Grazemax (12.19 t/ha) and Perseus (12.03 t/ha)
- Medium high producers (Light green): between 11.54 and 11.76 t/ha: Porthos, Storm, Tirna 4N Solid 4N and Cutmax Alfa
- Medium low producers (Dark green): between 10.36 and 10.95 t/ha: Perun, Achilles, Aramis, Citeliac, Becva and Niva
- Low producers (Yellow): between 8.93 and 9.57 t/ha: Versamax, Fotimo and Lofa

At PD 2, the DM production of cultivars could be classified in four groups. The DM production varied between 11.13 t/ha to 20.94 t/ha with Cutmax Alfa being the highest producer. The four identified groups were:

- High producer (Red): Cutmax Alfa with 20.94 t/ha (mixture)
- Medium high producers (Orange): Grazemax (15.96 t/ha) and Tirna 4N (15.83 t/ha)
- Medium low producers (Light green): 12 cultivars produced between 12.55 and 14.88 t/ha: Achilles, Solid 4N, Lofa, Perun, Perseus, Storm, Fotimo, Fotjan, Niva, Porthos, Citeliac and Aramis
- Low producers (Yellow): Versamax (11.29 t/ha) and Becva (11.13 t/ha)

The DM production of cultivars in PD 3 could be classified in three groups. The DM production ranged between 8.56 and 18.50 t/ha, with Porthos being the highest producing cultivar. The three production groups identified at this planting date are:

- High producer (Red): more than 16.67 t/ha: Porthos (*Dactylis* sp.) and Grazemax (mixture)
- Medium producer (Orange): between 12.34 and 16.67 t/ha: includes all cultivars except Porthos, Gracemax, Storm and Versamax
- Low producer (Yellow): Storm (9.99 t/ha) and Versamax (8.56 t/ha)

4.2.3.2 Summary

According to the results from Table 4.14, it is clear that cultivars responded differently to planting dates. The *Festulolium* hybrids (Fotjan and Perseus) and Grazemax (mixture) achieved the highest DM production in the early planting (PD 1). Mixtures (Cutmax Alfa and Grazemax) together with Tirna 4N (*Lolium* hybrid) were higher in PD 2. Porthos (*Dactylis spp*.), the mixtures (Grazemax and Cutmax Alfa), *Festulolium* hybrid (Becva) and *Lolium* hybrid (Solid 4N and Lofa) had higher DM production in PD 3. The Versamax mixture had the lowest DM production at all the planting dates.

If high production can be taken as a norm for successful establishment, it can be concluded that the majority if these cool season species and cultivars established and produced better the first season if planted late in April. The decrease of temperature towards autumn might be the reason for this.

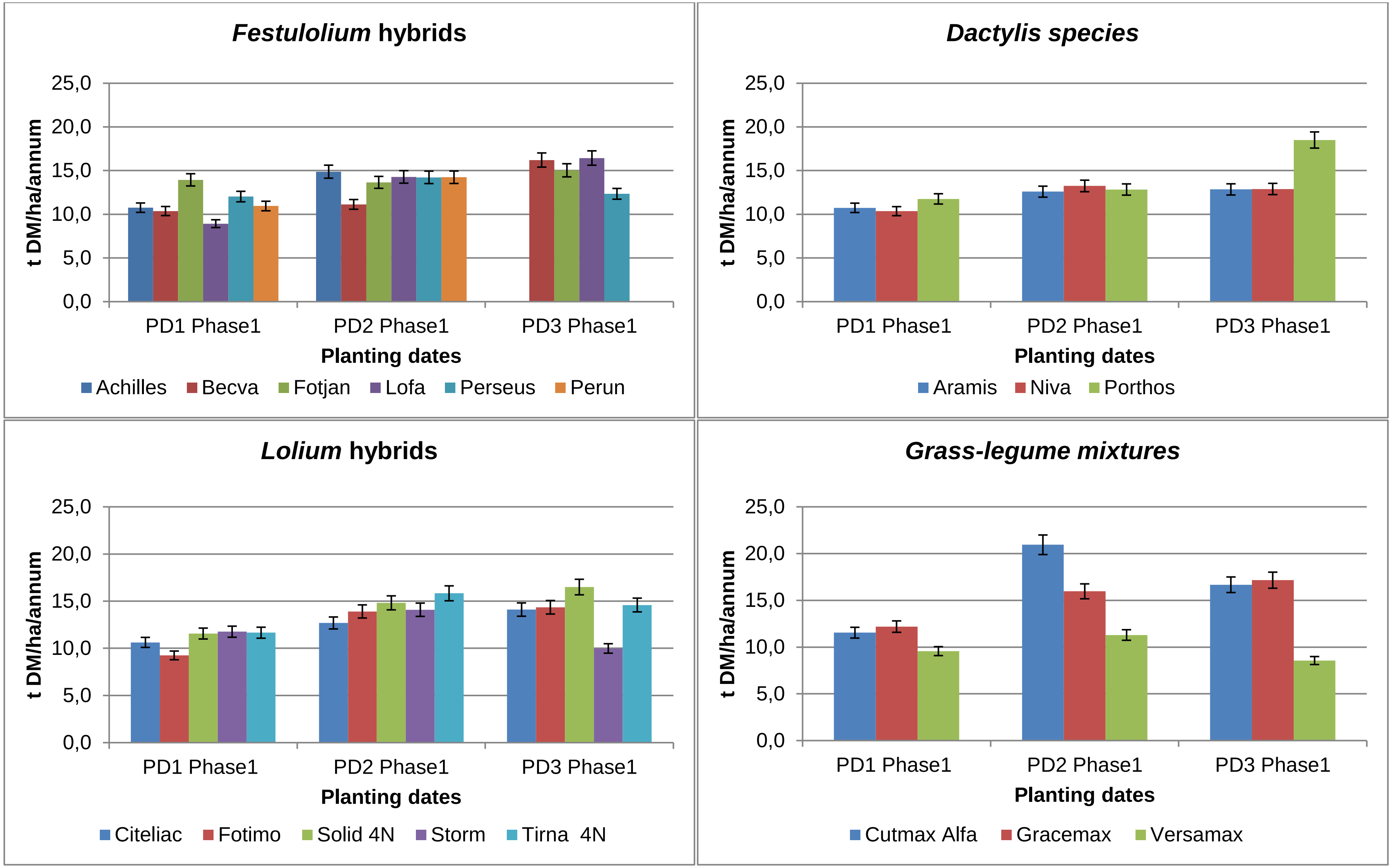

Figure 4.5: **The DM production (t/ha) of cultivars during Phase 1 (mid-summer) at three different planting dates**

4.2.4 The mid-winter (Phase 2) DM production as influenced by early and late planting dates (16 March and 21 April 2011).

Table 4.15: The planting dates and phases, marked green, were used in this division for the discussion in Paragraph 4.2.4

No	Planting date	Phase	Growing	Starting date	End date
1	16 March 2011	1	Mid-summer	06/09/2011	11/06/2012
		2	Mid-winter	05/12/2011	01/11/2012
2	21 April 2011	1	Mid-summer	28/09/2011	11/06/2012
		2	Mid-winter	16/01/2012	04/12/2012
		3	Mid-summer	11/06/2012	29/05/2013
3	04 April 2012	1	Mid-summer	11/06/2012	29/05/2013

All these species, cultivars and mixtures are cool season fodder crops and it was important to evaluate their winter production potential, when planted during early and late autumn.

4.2.4.1 The mid-winter DM production of *Festulolium* hybrids, *Dactylis species*, *Lolium* hybrids (average of cultivars) and mixtures as influenced by planting dates

According to Addendum 1.2, the DM production of species (as main effect) and mixtures did not differ significantly (P = 0.384) during the first mid-winter after been planted on 16 March 2011 (PD 1). According to Table 4.16 the DM productions varied between 12.69 and 15.36 t/ha. Addendum 2.2 indicates that the DM production of species differed significantly (P = 0.014) during the first mid-winter after been planted on 21 April 2011 (PD 2).

Table 4.16: The influence of the planting dates and species on average DM production in Phase 2 (mid-winter)

Planting dates	Species				Mean (t/ha)	LSD (5%)
	Festulolium	*Dactylis*	*Lolium*	Mixtures		
PD 1 (16 March 2011)	13.660	12.690	15.357	13.431	13.948	4.195
PD 2 (21 April 2011)	11.726	12.044	11.067	13.955	12.198	1.600

Results in Table 4.16, indicate that the DM production in the mid-winter was in general lower (not significantly) when planted in April 2011 than those planted in March 2011. On average, mixtures produced higher than *Festulolium* and *Lolium species*, while *Dactylis glomerata* filled an intermediate position.

According to Addendum 1.2.1, the DM production of cultivars (as main effect) did not differ significantly (P = 0.364) from each other in mid-winter (Phase 2) when planted in March 2011 (PD 1), while planting in April 2011 (PD 2) resulted in a significant (P = 0.001) difference (Addendum 2.2.1). The DM production results in the first mid-winter (Phase 2) after planting in March 2011 (PD 1) and April 2011 (PD 2) are shown in Table: 4.18 and also visually illustrated in Figure 4.6.

Table 4.17: The DM production (t/ha) of PD 1 (16 March 2011) and PD 2 (21 April 2011) of cultivars in Phase 2 (mid-winter)

PD 1 (16 March 2011) Add. 1.2.1			PD 2 (21 April 2011) Add. 2.2.1		
Fotjan	17.570	a	Cutmax Alfa	16.336	a
Solid 4N	17.429	a	Fotjan	15.128	a
Porthos	17.336	a	Grazemax	14.720	ab
Perseus	14.631	ab	Perun	12.554	bc
Cutmax Alfa	14.609	ab	Aramis	12.399	c
Tirna 4N	14.505	ab	Porthos	12.125	c
Grazemax	14.122	ab	Fotimo	11.974	c
Aramis	13.825	ab	Solid 4N	11.804	c
Niva	13.702	ab	Perseus	11.782	c
Perun	13.689	ab	Niva	11.607	c
Versamax	13.256	ab	Lofa	11.229	c
Citeliac	12.863	ab	Versamax	10.809	cd
Lofa	12.651	ab	Achilles	10.703	cd
Storm	12.533	ab	Citeliac	10.620	cd
Becva	11.715	b	Tirna 4N	10.494	cd
Achilles	11.377	b	Storm	10.442	cd
Fotimo	11.297	b	Becva	8.961	d
Average	13.948		Average	12.198	
LSD (5%)	5.316		LSD (5%)	2.213	

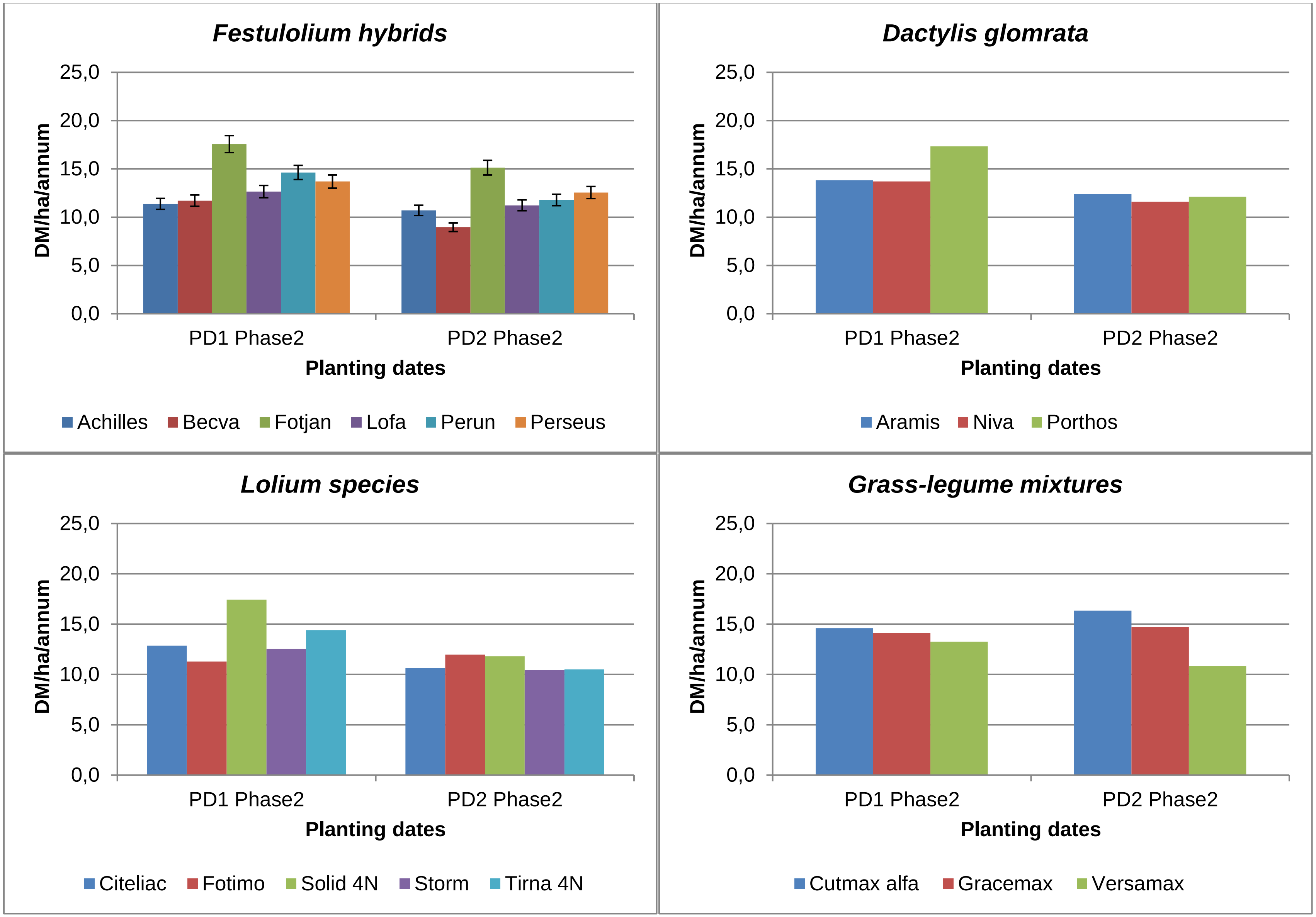

Figure 4.6: The DM production (t/ha) of cultivars in PD 1 (16 March 2011) and PD 2 (21 April 2011) during Phase 2 (mid-winter)

When comparing the results of cultivars that were planted in March 2011 (PD 1) in Table 4.17 with a Fischer's protected LSD of 5.316 (Addendum 1.2.1), three production groups were identified:

- High production group (Red): Fotjan (17.570 t/ha), Solid 4N (17.429 t/ha) and Porthos (17.336 t/ha)
- Medium production group (Orange): the following 11 cultivars produced between 12.533 t/ha and 14.631 t/ha: Perseus, Cutmax Alfa, Tirna 4N, Grazemax, Aramis, Niva, Perun, Versamax, Citeliac, Lofa, And Storm
- Low production group (Yellow): these three cultivars produced lower than 12 t/ha: Becva (11.715 t/ha), Achilles (11.377 t/ha) and Fotimo (11.297 t/ha)

If planted in April 2011 (PD 2), the DM production of the cultivars varied between 8.961 t/ha and 16.336 t/ha, with Becva being the lowest producer while Cutmax Alfa produced the highest. Four production groups were identified when comparing results with a Fischer's protected LSD of 2.213 (Addendum 2.2.1):

- High production group (Red): more than 14 t/ha: Cutmax Alfa (16.336 t/ha), Fotjan (15.128 t/ha) and Grazemax (14.720 t/ha)
- Medium high production group (Orange): between 11.229 t/ha and 12.554 t/ha: Perun, Aramis, Fotimo, Solid 4N, Perseus, Niva, and Lofa
- Medium low production group (Light green): between 10.442 t/ha and 10.804 t/ha: Versamax, Achilles, Citeliac, Tirna 4N, and Storm
- Low production group (Yellow): less than 10 t/ha including Becva

4.2.4.2 Summary

The time of planting had an effect on the DM production of *Festulolium* hybrids and *Lolium* hybrids during mid-winter. These two species performed, in general, better when planted earlier compared to the late planting date.

According to Table 4.17 and Figure 4.6, cultivars responded differently to the planting dates. *Festulolium* cv. Fotjan had the highest mid-winter DM production at both planting dates, whereas *Dactylis* cv. Porthos and *Lolium* cv. Solid 4N were higher when planted in March 2011 (PD 1). The grass-legume mixture Cutmax Alfa achieved the highest DM production when planted in April 2011

(PD 2). Becva had the lowest DM production at both planting dates, while Achilles and Fotimo were lower in the mid-winter of the first planting date.

It can be concluded that the *Festulolium* hybrid cultivars, Becva, Fotjan and Perseus produced, during the first winter, more than 2 t/ha higher at the March planting date than at the April planting date. The cultivars Niva and Porthos (*Dactylis spp*.) produced higher (± 2 t/ha) when planted in March. The cultivars Citeliac, Solid 4N, Storm and Tirna 4N (*Lolium spp*.) also produced more than 2 t/ha higher in the winter after planted in March 2011 (PD 1).

The mixtures Versamax produced higher in the first mid-winter when planted in March 2011 (PD 2), while Cutmax Alfa produced the best when planted in April. The production of Grazemax was not influenced by planting date.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary and conclusions

The aim of this study was to evaluate the production of perennial cool season fodder crops for the first two seasons after establishment in the warmer part of the summer rainfall area.

The results obtained in the different phases at the different planting dates were compared in the following different combinations:

- The effect of different fertilization levels on the DM production of all cultivars and mixtures during mid-summer when planted in March (Paragraph 4.2.1)
- Evaluation of DM production during first mid-summer, first mid-winter and second mid-summer after planting (Paragraph 4.2.2)
- The production during the first mid-summer of all the three planting dates at the medium fertilization level (Paragraph 4.2.3)
- The influence of planting dates (16 March 2011 and 21 April 2011) on the DM production during mid-winter (Paragraph 4.2.4)

5.1.1 The influence of fertilizing

The effect of different fertilization levels on the DM production of all cultivars and mixtures during mid-summer of the 16 March 2011 planting date are summarized in Table 4.7 (Paragraph 4.2.1).

From the results and discussions, it is clear that the low fertilization level (139 kg N + 66 kg P + 56 kg K/ha) resulted in the lowest DM production (below 11.5 t/ha) of all species and mixtures.

The medium and high fertilization levels did not influence production significantly. The four highest producing cultivars at the medium fertilization level produced between 11.7 and 13.9 t/ha, while it was between 13.3 and 15.1 t/ha at the high fertilization level.

5.1.2 DM production during first summer, first winter and second summer

The following conclusion can be made according to results obtained within the medium fertilizer level, during (a) the first summer, (b) the first winter and (c) the second summer season (according to Paragraph 4.2.2, Chapter 4).

Table 4.18: Summary of the high, medium and low productions during the three seasons of Planting date 2 (21 April 2011)

Production	First summer	First winter	Second winter
High	Above 15.8 t/ha	Above 12.5 t/ha	Above 16.4 t/ha
Medium	12.6 – 15.8 t/ha	11.2 – 12.5 t/ha	14.5 – 16.4 t/ha
Low	Below 12.6 t/ha	Below 11.2 t/ha	Below 14.5 t/ha

Festulolium hybrids

- Fotjan: Medium during summer, high in winter, high in the second summer
- Perun: Medium during summer, medium in winter, high in the second summer
- Lofa: Medium during summer, low in winter, high during the second summer
- Perseus: Medium during summer, medium in winter, medium in the second summer
- Achilles: Medium during summer, low in winter, low during the second summer
- Becva: Low during summer, low in winter, low during the second summer

Lolium hybrids

- Solid 4N: Medium during summer, medium in winter, high in the second summer
- Fotimo: Medium during summer, medium in winter, medium in the second summer
- Tirna 4N: High during summer, low in winter, low during the second summer
- Storm: Medium during summer, low in winter, low during the second summer
- Citeliac: Medium during summer, low in winter, low during the second summer

Dactylis species

- Aramis: Medium during summer, medium in winter, high in the second summer
- Porthos: Medium during summer, medium in winter, medium in the second summer
- Niva: High during summer, medium in winter, low during the second summer

Grass/legume mixtures

- The **Cutmax Alfa** mixture produced, on average, the highest DM during the first summer (20.9 t/ha) and declined tp 16.3 t/ha in winter and 16.7 t/ha in the second summer
- The grass-legume mixture **Grazemax** was also a high producer, with 15.9 t/ha, 14.5 t/ha and 18.3 t/ha, respectively, during the three season
- The grass-legume mixture **Versamax** was a relatively low producer during the first two seasons (below 11.3), but increased to 14.5 t/ha in the second summer

The continuous growth curves (Figure 4.4, Chapter 4) of the different grass cultivars (mixtures not included), are based on individual cuts from September 2011 to May 2013.

Most grass cultivars produced above 2.5t/ha/cut in the second and third cuts (October and November 2011), except Becva and Perun (both *Festulolium* hybrids). During the following autumn and winter (February to July) the production per cut of all cultivars declined to below 1.5 t/ha, except Perseus and Perun (both *Festulolium* hybrids). From August 2012 to February 2013 (second spring and summer), all cultivars showed, in general, an increase in production and after that a decrease in the second winter.

According to Figure 4.4, the results showed much fluctuation, but the following nine cultivars need special notification for the following reasons:

- Fotjan (*Festulolium* hybrid) was a higher producer in general, but production was low during winter.
- Becva, Perseus and Perun (*Festulolium* hybrids) were the cultivars with constant production over the full period (between 1.3 and 1.5 t/ha/cut).

- Perun (*Festulolium* hybrid) showed a significant increase in production towards the winter, while Perseus showed a high production during the first summer.
- Lofa (*Festulolium* hybrid) was an average producer, with a clear increase in production towards the second winter.
- Becva (*Festulolium* hybrid) produced on average, very low.
- Tirna 4N and Fotimo (both *Lolium* hybrids) are both average producers, with a clear increase in production towards the second summer. They were both high summer producer.s
- Niva (*Dactylis species*) started with a low production, but showed a significant increase in production towards the winter.
- Aramis (*Dactylis species*) showed fluctuations over the full period, increased in production towards the winter, which made it one of the best producers in the second summer.

5.1.3 The effect of planting date on production

If high production in the first summer is taken as a norm for successful establishment, it can be concluded that the majority of these cool season species and cultivars established and produced better in the first season if planted in April.

If high production in the first winter is taken as a norm for successful establishment, it can be concluded that most species and cultivars established and produced better when planted in late March.

There is thus a contradiction in whether the March or April planting date is the best and can it be included that establishment can be done in both months.

5.2 Recommendations/suggestions

The level of fertilizer for the grass species should be higher than 195 kg N + 85 kg P + 149 kg K/ha, but it should be dictated by economic principles.

Cultivars suggested for the warmer summer rainfall areas:

Festulolium hybrids: Fotjan, Perun, Lofa and Perseus

Lolium hybrids: Solid 4N, Fotimo and Tirna 4N

Dactylis species: Aramis

Grass-legume mixtures: Cutmax Alfa and Grazemax

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Addendum 1: The impact of fertilizer level on the DM production of the *Festulolium* hybrids, *Lolium* hybrids, *Dactylis species* and grass-legume mixtures on Phase 1 of Planting date 1 (16 March 2011) (Chapter 4: Figure 4.1, Figure 4.2, Figure 4.5 & Figure 4.6 and Table 4.4, Table 4.5, Table 4.6, Table 4.10, Table 4.11, Table 4.13 & Table 4.14)

Addendum 1.1: Comparing Species as main effects as influenced by fertilizers in PD 1 (16 March 2011) (Chapter 4: Table 4.4, Table 11, & Figure 4.1)

Analysis of variance

Variate: DM production (t/ha)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	2	409.45	204.725	24.14	
Main effect					
Fertiliser	2	342.847	171.423	20.21	0.008
Residual	4	33.922	8.48	1.27	
Sub effect					
Species	3	59.202	19.734	2.95	0.060
Interaction					
Fertiliser. Species	6	1.581	0.263	0.04	1.000
Residual	18	120.36	6.687	1.29	
Rep. Fertilizer .Species	117	607.425	5.192		
Total	152	1574.787			

Tables of means

Variate: DM production (t/ha)

Grand mean: 10.405					
Fertilizer	1	2	3		
	8.365	10.933	11.915		
Species	1	2	3	4	
	10.88	9.394	10.829	9.757	
rep.	54	27	45	27	
Fertilizer	Species	1	2	3	4
1		8.777	7.237	8.926	7.733
	rep.	18	9	15	9
2		11.33	10.122	11.334	10.284
	rep.	18	9	15	9
3		12.534	10.824	12.226	11.253
	rep.	18	9	15	9

Standard errors of means

Table	Fertilizer	Species	Fertilizer: Species
rep.	51	unequal	unequal
e.s.e.	0.4078	0.4976	0.8821

Least significant differences of means (5% level)

Table	Fertilizer	Species	Fertilizer: Species
rep.	51	unequal	unequal
l.s.d.	1.6011	1.4786	2.5882

Stratum standard errors and coefficients of variation

Variate: DM production (t/ha)

Stratum	d.f.	s.e.	cv%
Rep	2	2.0036	19.3
Rep.wplot	4	0.7063	6.8
Rep.wplot.splot1	18	*	*
Rep.wplot.splot1.*Units*	117	2.2785	21.9

=========== Comparing means ===========

Fisher's protected least significant difference test: Fertilizer

	Mean	
3	11.92	a
2	10.93	a
1	8.36	b

Fisher's protected least significant difference test: Species

Fisher's protected LSD is not calculated as variance ratio for Species is not significant.

Fisher's protected least significant difference test: Fertilizer: Species

Fisher's protected LSD is not calculated as variance ratio for Fertiliser. Species is not significant.

Addendum 1.1.1: Comparing Cultivars as main effects in terms of the influence of fertilizers in Phase 1 (mid-summer) of PD 1 (Chapter 4: Table 4.5, Table 4.6, and Table 4.11, Figure 4.2 & Figure 4.5)

Analysis of variance

Variate: DM production (t/ha)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replication	2	409.45	204.725	24.14	
Main effect					
Fertiliser	2	342.847	171.423	20.21	0.008
Residual	4	33.922	8.48	1.59	
Sub effect					
Cultivars	16	214.621	13.414	2.51	0.003
Fertilizer. Cultivars	32	60.577	1.893	0.35	0.999
Residual	96	513.37	5.348		
Total	152	1574.787			

Tables of means

Grand mean: 10.405

Fertilizer	1	2	3
	8.365	10.933	11.915

Cultivars	1	2	3	4	5	6	7	8	
	9.7	8.591	12.991	9.076	11.226	10.707	10.643	9.694	
Cultivars	9	10	11	12	13	14	15	16	17
	11.302	11.237	8.518	11.213	10.316	10.216	12.12	10.589	9.449

Fertilizer	Cultivars	1	7	2	10	15	3	11	16
1		7.209	8.137	6.218	9.667	11.495	9.936	6.058	8.201
2		10.756	10.739	10.373	10.628	11.541	13.945	9.249	12.19
3		11.134	13.052	9.181	13.416	13.324	15.094	10.248	11.376

Fertilizer	Cultivars	4	8	5	6	9	12	13	14
1		7.452	7.752	9.075	9.328	10.071	8.405	8.326	7.696
2		8.928	10.359	12.031	10.95	11.763	11.566	11.762	11.655
3		10.847	10.971	12.573	11.844	12.072	13.668	10.859	11.297

Fertilizer	Cultivars	17
1		7.177
2		9.569
3		11.602

Standard errors of means

Table	Fertilizer	Cultivars	Fertilizer. Cultivars
rep.	51	9	3
e.s.e.	0.4078	0.7708	1.3579

Least significant differences of means (5% level)

Table	Fertilizer	Cultivar	Fertilizer. Cultivars
rep.	51	9	3
l.s.d.	1.6011	2.1639	3.8131

========== Comparing means ==========

Fisher's protected least significant difference test: Cultivars

	Mean	
3	12.99	a
15	12.12	ab
9	11.30	abc
10	11.24	abcd
5	11.23	abcd
12	11.21	abcd
6	10.71	bcde
7	10.64	bcdef
16	10.59	bcdef
13	10.22	bcdef
14	9.70	cdef
1	9.69	cdef
8	9.60	cdef
17	9.45	cdef
4	9.08	def
2	8.59	ef
11	8.52	f

Fisher's protected least significant difference test: Fertilizer. Cultivars

Fisher's protected LSD is not calculated as variance ratio for Fertilizer. Cultivar is not significant.

Addendum 1.2: Comparing Species as main effects as influenced by PD 1 (16 March 2011) in Phase 2 (mid-winter) (Chapter 4: Table 4.13)

Analysis of variance

Variate: DM production (t/ha)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	101.405	50.702	3.83	
Rep.wplot1 stratum					
Species	3	47.937	15.979	1.21	0.384
Residual	6	79.361	13.227	1.34	
Rep.wplot1.*Units* stratum	39	385.826	9.893		
Total	50	614.528			

Tables of means

Variate: DM production (t/ha)

Grand mean: 13.948

Species	1	2	3	4
	13.66	12.69	15.357	13.431
rep.	18	9	15	9

Standard errors of means

Table	Species
rep.	unequal
d.f.	6
e.s.e.	1.2123

Least significant differences of means (5% level)

Table	Species
rep.	unequal
d.f.	6
l.s.d.	4.1951

Stratum standard errors and coefficients of variation

Variate: DM production (t/ha)

Stratum	d.f.	s.e.	cv %
Rep	2	1.727	12.4
Rep.wplot1	6	*	*
Rep.wplot1.*Units*	39	3.1453	22.6

Fisher's protected least significant difference test: Species

Fisher's protected LSD is not calculated as variance ratio for Species is not significant.

Addendum 1.2.1: Comparing Cultivars as main effects as influenced by PD 1 (16 March 2011) in Phase 2 (Mid-winter) (Chapter 4: Table 4.14 & Figure 4.6)

Analysis of variance

Variate: DM production (t/ha)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	101.4	50.7	4.96	
Rep.wplot2 stratum					
Cultivar	16	186.21	11.64	1.14	0.364
Residual	32	326.92	10.22		
Total	50	614.53			

Tables of means

Grand mean: 13.948

Cultivar								
1	2	3	4	5	6	7	8	9
11.377	11.715	17.57	12.651	14.631	13.689	13.825	13.702	17.336
Cultivar								
10	11	12	13	14	15	16	17	
12.863	11.297	17.429	12.533	14.505	14.609	14.122	13.256	

Standard errors of means

Table	Cultivars
rep.	3
d.f.	32
e.s.e.	1.8454

Least significant differences of means (5% level)

Table	Cultivars
rep.	3
d.f.	32
l.s.d.	5.3159

Stratum standard errors and coefficients of variation

Variate: DM production (t/ha)

Stratum	d.f.	s.e.	cv %
Rep	2	1.727	12.4
Rep.wplot2	32	3.1963	22.9

Fisher's protected least significant difference test: Cultivars

Fisher's protected LSD is not calculated as variance ratio for Cultivars is not significant.

Addendum 2: Evaluation of total DM production during all three Phases (first mid-summer, mid-winter and second mid-summer) of the second Planting date (21 April 2011) (Chapter 4: Figure 4.3, Figure 4.4, Figure 4.5, Figure 4.6, Table 4.8, Table 4.9 Table 4.10, Table 11, Table 4.13 & Table 4.14)

Addendum 2.1: Comparing Species as main effects as influenced by mid-summer (Phase 1) in PD 2 (21 April 2011) (Chapter 4: Table 4.9 & Table 4.11)

Analysis of variance

Variate: DM production (t/ha)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	86.176	43.088	4.89	
Rep.splot1 stratum					
Species	3	50.57	16.857	1.91	0.228
Residual	6	52.827	8.804	0.9	
Rep.splot1.*Units* stratum	39	380.177	9.748		
Total	50	569.751			

Tables of means

Grand mean: 14.2405

Species	1	2	3	4
	13.737	12.891	14.268	16.066
rep.	18	9	15	9

Standard errors of means

Table	Species
rep.	unequal
d.f.	6
e.s.e.	0.9891

Least significant differences of means (5% level)

Table	Species
rep.	unequal
d.f.	6
l.s.d.	3.4227

Stratum standard errors and coefficients of variation

Variate: DM production (t/ha)

Stratum	d.f.	s.e.	cv %
Rep	2	1.592	11.2
Rep.splot1	6	*	*
Rep.splot1.*Units*	39	3.1222	22.1

========== Comparing means ==========

Fisher's protected least significant difference test: Species

Fisher's protected LSD is not calculated as variance ratio for Species is not significant.

========== Summary of original data =========

Species	No. observed	Mean	s.d.
1	18	13.74	2.247
2	9	12.89	1.655
3	15	14.27	3.402
4	9	16.07	4.183

Addendum 2.1.1: Comparing Cultivars as main effects as influenced by mid-summer (Phase 1) in PD 2 (21 April 2011) (Chapter 4: Table 4.10, Table 4.12 & Figure 4.3, Figure 4.4 and Figure 4.5)

Analysis of variance

Variate: DM production (t/ha)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	86.176	43.088	5.52	
Rep.splot2 stratum					
Cultivars	16	233.91	14.619	1.87	0.064
Residual	32	249.665	7.802		
Total	50	569.751			

Tables of means

Grand mean: 14.2405

Cultivar	1	2	3	4	5	6	7	8	9
	14.88	11.134	13.657	14.279	14.23	14.241	12.590	13.246	12.837
Cultivar	10	11	12	13	14	15	16	17	
	12.686	13.909	14.82	14.090	15.831	20.943	15.963	11.291	

Standard errors of means

Table	Cultivars
rep.	3
d.f.	32
e.s.e.	1.6127

Least significant differences of means (5% level)

Table	Cultivars
rep.	3
d.f.	32
l.s.d.	4.6455

Stratum standard errors and coefficients of variation

Variate: DM production (t/ha)

Stratum	d.f.	s.e.	cv %
Rep	2	1.592	11.2
Rep.splot2	32	2.7932	19.7

Fisher's protected least significant difference test: Cultivars

Fisher's protected LSD is not calculated as variance ratio for Cultivars is not significant.

========== Summary of original data =========

Cultivar	No. observed	Mean	s.d.
1	3	14.88	4.120
2	3	11.13	0.623
3	3	13.66	0.693
4	3	14.28	0.761
5	3	14.23	1.464
6	3	14.24	3.005
7	3	12.59	3.858
8	3	13.25	2.605
9	3	12.84	2.489
10	3	12.69	2.876
11	3	13.91	1.789
12	3	14.82	1.971
13	3	14.09	3.192
14	3	15.83	6.883
15	3	20.94	4.934
16	3	15.96	2.122
17	3	11.29	2.949

Addendum 2.2: Comparing Species as main effects as influenced by mid-winter (Phase 2) in PD 2 (21 April 2011) (Chapter 4: Table 4.14)

Analysis of variance

Variate: DM production (t/ha)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	175.679	87.839	45.65	
Rep.splot1 stratum					
Species	3	48.812	16.271	8.46	0.014
Residual	6	11.545	1.924	0.45	
Rep.splot1.*Units* stratum	39	164.951	4.23		
Total	50	400.987			

Tables of means

Variate: DM production (t/ha)

Grand mean: 12.198

Species	1	2	3	4
	11.726	12.044	11.067	13.955
rep.	18	9	15	9

Standard errors of means

Table	Specie
rep.	unequal
d.f.	6
e.s.e.	0.4624

Least significant differences of means (5% level)

Table	Species
rep.	unequal
d.f.	6
l.s.d.	1.6

Stratum standard errors and coefficients of variation

Variate: DM production (t/ha)

Stratum	d.f.	s.e.	cv %
Rep	2	2.2731	19
Rep.splot1	6	*	*
Rep.splot1.*Units*	39	2.0566	17.2

Fisher's protected least significant difference test: Species

	Mean	
4	13.95	a
2	12.04	b
1	11.73	b
3	11.07	b

========== Summary of original data =========

Species	No. observed	Mean	s.d.
1	18	11.73	2.908
2	9	12.04	1.545
3	15	11.07	2.357
4	9	13.96	3.733

Addendum 2.2.1: Comparing Cultivars as main effects as influenced by mid-winter (Phase 2) in PD 2 (21 April 2011) (Chapter 4: Table 4.15 & Figure 4.6)

Analysis of variance

Variate: DM production (t/ha)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	175.679	87.839	49.63	
Rep.splot2 stratum					
Cultivars	16	168.673	10.542	5.96	<.001
Residual	32	56.635	1.77		
Total	50	400.987			

Tables of means

Grand mean: 12.198

Cultivars								
1	2	3	4	5	6	7	8	9
10.703	8.961	15.128	11.229	11.782	12.554	12.399	11.607	12.125
Cultivars								
10	11	12	13	14	15	16	17	
10.62	11.974	11.804	10.442	10.494	16.336	14.72	10.809	

Standard errors of means

Table	Cultivars
rep.	3
d.f.	32
e.s.e.	0.7681

Least significant differences of means (5% level)

Table	Cultivars
rep.	3
d.f.	32
l.s.d.	2.2126

Stratum standard errors and coefficients of variation

Variate: DM production (t/ha)

Stratum	d.f.	s.e.	cv %
Rep	2	2.2731	19
Rep.splot2	32	1.3304	11.1

Fisher's protected least significant difference test: Cultivars

	Mean	
3	15.128	a
15	16.336	a
16	14.720	ab
6	12.554	bc
7	12.399	c
9	12.125	c
11	11.973	c
12	11.804	c
5	11.782	c
8	11.607	c
4	11.229	c
17	10.809	cd
1	10.703	cd
10	10.620	cd
14	10.494	cd
13	10.442	cd
2	8.961	d

Addendum 2.3: Comparing Species as main effects as influenced by mid-summer (Phase 3) in PD 2 (21 April 2011) (Chapter 4: Table 9)

Analysis of variance

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	128.344	64.172	30.3	
Rep.splot1 stratum					
Species	3	26.85	8.95	4.23	0.063
Residual	6	12.707	2.118	0.23	
Rep.splot1.*Units* stratum	39	353.934	9.075		
Total	50	521.835			

Tables of means

Variate: TDM production (t/ha)

Grand mean: 15.209

Species	1	2	3	4
	14.76	15.107	14.439	16.53
rep.	18	9	15	9

Standard errors of means

Table	Species
rep.	unequal
d.f.	6
e.s.e.	0.4851

Least significant differences of means (5% level)

Table	Species
rep.	unequal
d.f.	6
l.s.d.	1.6787

Stratum standard errors and coefficients of variation

Variate: TDM production (t/ha)

Stratum	d.f.	s.e.	cv %
Rep	2	1.9429	12.9
Rep.splot1	6	*	*
Rep.splot1.*Units*	39	3.0125	20

========== Comparing means ==========

Fisher's protected least significant difference test: Species

Fisher's protected LSD is not calculated as variance ratio for Species is not significant.

Addendum 2.3.1: Comparing Species as main effects as influenced by mid-summer (Phase 3) in PD 2 (21 April 2011) (Chapter 4: Table 4.10, Figure 4.3 & Figure 4.4)

Analysis of variance

Variate: TDM production (t/ha)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	128.344	64.172	10.75	
Rep.splot2 stratum					
Cultivars	16	202.418	12.651	2.12	0.035
Residual	32	191.074	5.971		
Total	50	521.835			

Tables of means

Variate: TDM production (t/ha)

Grand mean 15.039

Cultivars								
1	2	3	4	5	6	7	8	9
11.382	12.189	18.697	14.677	14.962	16.651	17.024	13.379	14.917
Cultivars								
10	11	12	13	14	15	16	17	
13.007	15.094	16.446	13.9	13.749	16.732	18.346	14.512	

Standard errors of means

Table	Cultivars
rep.	3
d.f.	32
e.s.e.	1.4108

Least significant differences of means (5% level)

Table	Cultivars
rep.	3
d.f.	32
l.s.d.	4.064

Stratum standard errors and coefficients of variation

Variate: TDM production (t/ha)

Stratum	d.f.	s.e.	cv %
Rep	2	1.9429	12.9
Rep.splot2	32	2.4436	16.2

========== Comparing means ==========

Fisher's protected least significant difference test: Cultivars

	Mean	
3	18.697	a
16	18.348	ab
7	17.025	abc
15	16.732	abc
6	16.651	abc
12	16.446	abc
11	15.094	abcd
5	14.962	abcd
9	14.918	abcd
4	14.677	abcd
17	14.512	bcd
13	13.900	cd
14	13.749	cd
8	13.379	cd
10	13.007	cd
2	12.189	d
1	11.382	d

Addendum 3: Winter grazing trial: Phase 1 (mid-summer) on Planting date 3 (4 April 2012) (Table 4.11, Table 4.12 and Figure 4.5)

Addendum 3.1: Comparing Species as main effects as influenced by mid-summer (Phase 1) in PD 3 (04 April 2012) (Chapter 4: Table 4.11)

Analysis of variance

Variate: DM production (t/ha)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	220.37	110.19	7.65	
Rep.splot1 stratum					
Species	3	10.01	3.34	0.23	0.871
Residual	6	86.47	14.41	0.69	
Rep.splot1.*Units* stratum	33	687.68	20.84		
Total	44	1004.54			

Tables of means

Variate: DM production (t/ha)

Grand mean: 14.413

Species	1	2	3	4
	15.008	14.75	13.906	14.128
rep.	12	9	15	9

Standard errors of means

Table	Species
rep.	unequal
d.f.	6
e.s.e.	1.2655

Least significant differences of means (5% level)

Table	Species
rep.	unequal
d.f.	6
l.s.d.	4.379

Stratum standard errors and coefficients of variation

Variate: DM production (t/ha)

Stratum	d.f.	s.e.	cv %
Rep	2	2.7103	18.8
Rep.splot1	6	*	*
Rep.splot1.*Units*	33	4.5649	31.7

Fisher's protected least significant difference test: Species

Fisher's protected LSD is not calculated as variance ratio for Species is not significant.

Addendum 3.1.1: Comparing Cultivars as main effects as influenced by mid-summer (Phase 1) in PD 3 (04 April 2012) (Chapter 4: Table 4.12 & Figure 4.5)

Analysis of variance

Variate: DM production (t/ha)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	220.37	110.19	6.55	
Rep.splot2 stratum					
Cultivar	14	313.28	22.38	1.33	0.251
Residual	28	470.88	16.82		
Total	44	1004.54			

Tables of means

Grand mean: 14.413

Cultivar	2	3	4	5	6	7	8	9
	16.213	15.037	16.441	12.343	12.848	12.897	18.504	14.108
Cultivar	10	11	13	14	15	16	17	
	14.351	16.495	9.986	14.591	16.667	17.156	8.560	

Standard errors of means

Table	Cultivars
rep.	3
d.f.	28
e.s.e.	2.3676

Least significant differences of means (5% level)

Table	Cultivars
rep.	3
d.f.	28
l.s.d.	6.8588

Stratum standard errors and coefficients of variation

Variate: DM production (t/ha)

Stratum	d.f.	s.e.	cv %
Rep	2	2.7103	18.8
Rep.splot2	28	4.1009	28.5

Fisher's protected least significant difference test: Cultivars

Fisher's protected LSD is not calculated as variance ratio for Cultivars is not significant.