EVALUATION OF FINGER MILLET (*Eleusine coracana*) UNDER IRRIGATED AND RAINFED CONDITIONS AS A FODDER CROP ON THE PIETERSBURG PLATEAU, SOUTH AFRICA

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DECLARATION

I hereby declare that this mini-dissertation entitled “EVALUATION OF FINGER MILLET (*Eleusine coracana*) UNDER IRRIGATED AND RAINFED CONDITIONS AS A FODDER CROP ON THE PIETERSBURG PLATEAU, SOUTH AFRICA” is my original work and that it has not been submitted by me and will not be presented at any university for any other degree. All the quoted and sources used have been acknowledged by means of a complete reference list.

Maenetja N.P

Signature: -- Date: ---------------------------------------

DEDICATION

I dedicate this work to my daughters PHENYO and MORERO MAENETJA.

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I would like to express my sincere gratitude to the following people:

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- To the rest of my family all who, in one way or the other, contributed significantly to the success of this study.

To all individuals acknowledged above: May God shower rewards to all of you abundantly. Above all, Glory and Honour to GOD, ALMIGHTY for bestowing unto me His mercy, care, strength, health and wisdom during the entire period of study and beyond.

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ABSTRACT

Finger millet (*Eleusine coracana)* is believed to be adapted to the arid and semi-arid regions, highly tolerant to pests, diseases and drought. It has the potential to produce a high forage biomass with fewer inputs under good production practices. The aim of the study was to evaluate the potential of finger millet as a fodder crop on the Pietersburg Plateau under rainfed and irrigation conditions, planted in rows and broadcast. The study was conducted for two consecutive seasons (2017 and 2018) at the Syferkuil Experimental Farm (SEF), University of Limpopo.

Treatments consisted of two watering treatments (irrigation and rainfed) and two planting methods (broadcast and row planting). Seeding rate was 10 kg ha^{-1} with the inter row spacing of 25 cm. Irrigation had a significant effect on the dry matter production of finger millet (P ≤ 0.05). During 2017 growing season, under rainfed condition, the crop experienced zero production due to low rainfall. The total dry matter production of finger millet under rainfed conditions in 2018 was 3371 kg ha^{-1} for row planting and 3770 kg ha^{-1} for broadcasting. The dry matter production of finger millet under irrigation and row planting was 5318 kg ha^{-1} compared to 3371 kg ha^{-1} produced under row planting in the rainfed conditions. Broadcasting under irrigation produced 4890 kg ha^{-1} whereas broadcasting under rainfed conditions yielded 3770 kg ha^{-1}. Planting method had no significant effect on the dry matter production of finger millet (P ≤ 0.05). The total dry matter production in 2017 was 5668 kg ha^{-1} and 5122 kg ha^{-1} under row planting and broadcast respectively, 2018 season produced the total dry matter production of 5122 kg ha^{-1} under row planting and 4892 kg ha^{-1} under broadcast. Finger millet planted under rainfed in rows had the CP% of 14.76 and 16.87% when broadcasted. In all the treatments CP% was higher than 10%. The ADF% was 33.02% under rainfed conditions and it ranged between 30.99% and 31.53% in 2017 and 2018 for row planting under irrigation. Finger millet can be considered an alternative fodder crop for livestock farmers in the Pietersburg Plateau.

Keywords: Broadcast, finger millet, irrigation, rainfed, and rows

CHAPTER 1

1. GENERAL INTRODUCTION

1.1 Background of the study

Finger millet (*Eleusine coracana*) is a staple food crop grown by subsistence farmers in the semi-arid tropics and sub-tropics of the world under rainfed conditions (Upadhyaya *et al*., 2013). It is cultivated in more than 25 countries, mainly in Africa (Ethiopia, Eritrea, Mozambique, Zimbabwe, Namibia, Senegal, Niger, Nigeria, and Madagascar) and Asia (India, Nepal, Malaysia, China, Japan, Iran, Afghanistan, and Sri Lanka) (Kruska *et a*l., 2003). In India, finger millet is primarily grown in the states of Karnataka, Andhra Pradesh, Odisha, and Tamil Nadu (Kannaiyan *et al*., 1984). In Eastern Africa, the major producers are Uganda, Ethiopia and Kenya (Thilakarathna and Raizada 2015). The name "finger millet" is derived from the seed-head, which has the shape of human fingers (Wafula *et al*., 2017). Finger millet is highly valued by local farmers in East Africa for its ability to grow in adverse agro climatic conditions, where cereal crops such as maize (*Zea mays*), wheat (*Triticum spp*.) and rice (*Oryza sativa*) fail to tolerate a wide variety of soils (Rengel *et al*., 1999). The emerging global warming scenario has also made finger millet a good potential crop to be used for multiple purposes (Wafula *et al*., 2017). However, finger millet continues to remain underutilised in Southern Africa, despite numerous benefits and advantages (Ruel *et al*., 2013).

1.2 Problem statement

Finger millet is considered as the forgotten crop of Africa and it is grossly neglected scientifically and internationally (Shinggu *et al*., 2009), as compared to research conducted on wheat, rice and maize. Finger millet has the potential to produce a fairly high grain and forage yield with fewer use of inputs provided good crop husbandry is followed (Wafula *et al*., 2017). Information on finger millet as a fodder crop in South Africa is scarce and non-existent in the Limpopo Province. It is mostly grown in developing sub-Saharan African countries by resource poor, communal farmers, who depend on self-produced landraces as seed sources. Consequently, it is an unknown crop in South Africa. The recent interest in pasture crops such as Bana grass, *Phalaris* *tuberosa*, *Tagasaste* and *Leucaena*, all of which have proven to be unsuccessful in South Africa. This has highlighted the need for additional low input fodder crops that are adapted for South African conditions in terms of both quantity and quality, especially where drought tolerance and tolerance to grazing are concerned.

1.3 Rationale of the study

Finger millet provides excellent hay and can be used as green forage for cattle, sheep and goats (El Shaer, 2010). In addition, straw can be grazed by animals or used in cut-and-carry feeding systems (Salem *et al*., 2010). Furthermore, finger millet contains up to 61% total digestible nutrients (Mohamed *et al*., 2009). It is a fast growing crop, reaching maturity within three to four months and might be highly beneficial in a fodder flow system (Fetene *et al*., 2011). However, the use of finger millet in livestock systems as a rainfed crop for green chop forage, silage, grazing or as a cover crop has not been researched in South Africa (Landers, 2007).

Among the modern agro-management techniques, planting method (Bakht *et al*., 2011) and irrigation are the crucial factors for improving crop biomass. In order to achieve yield increases of this forgotten crop, there is a need to quantify how management practices influence growth and yield of the crop. This study was therefore conducted to provide baseline data in terms of the above ground biomass and chemical composition of finger millet as a fodder crop, ultimately to identify and develop 'best management practices' to intensify fodder production in Limpopo Province, South Africa.

1.4 Purpose of the study

1.4.1 Aim

The aim of the study was to evaluate the potential of finger millet as a fodder crop in the Pietersburg Plateau under rainfed and irrigation conditions, sown in rows and broadcasting method.

1.4.2 Objectives

The objectives of the study were

i. To measure the effect of irrigation and planting method on the dry matter production of finger millet.
ii. To quantify the nutritional value of finger millet as influenced by irrigation and planting method.

1.4.3 Hypotheses

i. Irrigation and planting method have no effect on the dry matter production of finger millet.
ii. Irrigation and planting method have no effect on the nutritional value of the above ground biomass of finger millet.

CHAPTER 2

2. LITERATURE REVIEW

2.1 Introduction

This chapter provides literature of exiting knowledge from different authors with the aim of discussing different viewpoints and results to understand and evaluate the potential of finger millet as a fodder crop under rainfed and irrigated conditions, planted in rows and broadcast methods.

2.2 General information on finger millet

Finger millet is a forage grass also known as Koracan (Nigeria), Ragi (India), Bulo (Uganda), Wimbi (Swahili), and Telebun (Sudan) (Gowda et al., 2015). It is cultivated on more than 3600000 ha globally and 2000000 ha is grown in India in a region receiving rainfall less than or comparable to the Southern High Plains (Cassman, 1999). Finger millet (*Eleusine coracana* subspecies *coracana*) is a fodder crop that belongs to the family Poaeceae (Hilu and Wet 1976). Finger millet is a tufted annual crop that can grow to heights of between 30 and 150 cm. Furthermore, this fodder crop matures between and after 75 to 160 days. According to Jyoti and Kumar (2017), the leaves of the finger millet are narrow and grass-like capable of producing many tillers and nodal branches. The panicle of the finger millet consists of a group of digitally arranged spikes, often referred to as fingers. The spikelets are made up of 4 to 10 florets arranged serially on the finger (Abrams, 1940). All florets are perfect flowers with the exception of the terminal ones, which may sometimes be infertile (Shinggu *et al*., 2009). The grain is oblong to round and oval, reddish brown in colour with its grains' surface finely corrugated (Shinggu *et al*., 2009).

2.2.1 The history of finger millet

Cytomorphological studies indicated, that finger millet might have originated from wild *Eleusine africana* through selection in Ethiopia and the highlands of Africa (Assefa *et a*l., 2011). Evans (1996) stated that finger millet was introduced in India about 3000 years ago and has since become the secondary centre of finger millets' diversity. The cultivated *Eleusine coracana* is a tetraploid and exhibits morphological similarity to both *Eleusine indica* and *Eleusine africana* (Upadhyaya, 2009). It was earlier thought that cultivated *Eleusine coracana* originated from *Eleusine indica*, and was later distributed through Africa eastwards to Java. The cytological evidence indicates that *Eleusine indica* has contributed one of the genomes to the cultivated *Eleusine coracana*, which is an allotetraploid (Upadhyaya, 2009). The species *Eleusine africana*, which is also a tetraploid, exhibits great similarity in morphological feature with *Eleusine coracana*. This indicates that they are genetically related and their gene flow occurs between them in nature, suggesting that *Eleusine coracana* originated from *Eleusine africana* through selection and further mutation towards larger grains (Ellstrand *et al*., 1999).

Archaeological findings indicate that the finger millet dates back to the third millennial BC from Ethiopia (Hilu *et al*., 1979). The two distinct races of the finger millet recognized are the African highlands race and Afro-asiatic lowland race (Hilu and De Wet 1976). The African highlands race are considered to be derived from *Eleusine africana* under cultivation and this gave rise to the African lowland race, which later migrated to India and developed as the Afro-Asiatic lowland race (Sood and Babu 2016). This migration of finger millet to the Indian sub-continent is likely to have occurred around 3000 BC (Doggett, 1991). Studies of the patterns of variability in African and Asian finger millets has by and large indicated relatively larger diversity in African germplasm compared to Indian collections, lending support to the view that Africa could be the primary centre of origin (Krishna, 2010).

The long history of cultivation in the Indian subcontinent for more than 5000 years since then, accompanied by human selection, has resulted in the generation of large diversity in landraces and local cultivars in India (Zaharieva *et al*., 2010). Close studies of various characters in Indian germplasm have revealed that the Indian germplasm possesses large variability, indicating India as the secondary centre of diversity (Patil, 2013). For economic purposes, this occurred due the following important characters: the finger length, finger width, finger number, grain yield, ear weight, total biomass and leaf number (Patil, 2013). Finger millet is thus considered to have been domesticated at the beginning of the Iron Age in Africa and was introduced into India 5000 years ago before spreading to South-East Asia (Zohary *et al*., 2012). It is currently widespread in warm temperate regions from Africa to Japan and Australia, but can also grow in colder regions as far north as Northern Ireland, during summer (Allaby, 2012).

The worldwide area under finger millet has declined from 2600000 ha in the early sixties to around 1660000 ha with the production area of 38000000 ha in 2003-04 (Upadhyaya *et al*., 2009). However, the annual grain production is maintained around 2600000 kg with a productivity of around 1400 kg ha^{-1} (Derera, 2005). Finger millet is the fourth most important millet in terms of the worldwide production after sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*) and foxtail millet (*Setaria italica*) (Upadhyaya *et al*., 2009). However, in Africa, finger millet is the second most important fodder crop and represents 19% of millet production, after pearl millet (76%) (Jideani, 2012).

Finger millet is the main small millet species grown in South Asia (Baltensperger, 2002). In 2006, finger millet grain production was approximately 4500000 kg: where 2000000 kg were produced in Africa with a production area of 19000000 ha (mainly Eastern and Southern African), while the Asian continent (mainly India, followed by Nepal) produced the re mainder (Lacy *et al*., 2006). However, Asian production keeps growing (by 50% in India during the last fifty years and by 8% per year in Nepal) and African production remains unchanged. The average yield of the rainfed crop ranges from 1000 to 1500 kg ha^{-1}, whereas irrigation yields up to 5000 kg ha^{-1} (Liu *et a*l., 2007).

2.3 Uses of finger millet

Finger millet seeds have a moisture content of 6.99 % (David et al., 2014). This is advantageous because they can be stored for long periods without spoilage (Deshmukh *et al*., 2014). While grains are used for human consumption, the crop residues are an excellent source of dry matter for livestock, especially in dry seasons (Itabari *et al*., 2011). Consequently, humans avoid eating coarse roughages, but they can be transformed into economic products by livestock (Wafula *et al*., 2017). Romero-González *et al*. (2010), further stated that finger millet is mainly grown for food grain for human consumption and for brewing alcoholic/non-alcoholic beverages.

Major crops, especially cereals, produce large quantities of stem and leaf in addition to their saleable product, which is usually the seed (Wafula *et al*., 2017). According to Andrews and Kumar (1992), better quality silage can be made during its flowering stage. Finger millet can be a second rainfed crop for green chop, silage, grazing or cover crop (Landers, 2007). It has the potential to produce high grain quantity and dry matter yield with fewer use of inputs if good crop husbandry is followed (Wafula *et al*., 2017). Finger millet stover has also been documented to make good fodder and contains up to 61% total digestible nutrients (Pearson *et al*., 2001). Its straw is used for feeding livestock in many Asian and African countries (Wafula *et al*., 2017). It therefore offers opportunity for development of a thriving livestock industry (Wafula *et al*., 2017). On the other hand, straw makes valuable fodder for both strong and sturdy and milk producing animals (Hassen *et al*., 2010). The straw or stover is usually over half the harvestable vegetation of the crop. Other positive traits of finger millet include drought tolerance, disease resistance, weeds suppression and long shelf life (Snow and Palma 1997).

2.4 Growth requirements of finger millet

Finger millet is commonly found at altitudes of between 1000 and 2000 m above sea level in eastern and southern Africa, and between 2500 and 3000 m in the Himalayas (Hailu and Gebreyohans 2017). It can grow in area with an annual rainfall ranging from 500 to 1000 mm, provided it is well distributed across the growing season (David *et al*., 2014). It is generally considered as a drought tolerant crop, but compared with other millets, such as pearl millet and sorghum, it prefers moderate rainfall of less or equal to 500 mm annually (Prasad and Staggenborg 2009). Finger millet will keep growing in drier conditions, but pearl millet and sorghum prefers rainfall below 500 mm (David *et al*., 2014). It is intolerant to flooded conditions but withstands some waterlogging (David *et al*., 2014). It does not do well in areas of heavy rains, but prefers damp conditions (Lewandowski *et al*., 2003). It is generally grown as a rainfed crop, although yields can often be significantly improved when irrigation is applied. In India, finger millet is a typical Rabi (dry season) crop (David *et al*., 2014). It grows best at an average temperature of 23°C but can withstand cooler and hotter conditions (Armson *et al*., 2012).

Finger millet is adapted to a wide range of soil conditions, though it prefers fertile, well-drained sandy to sandy loam soils with a pH ranging from 5 to 7 (David *et al*., 2014). However, it will grow in lateritic or black heavy vertisols and has some tolerance to alkaline and moderately saline soils. It has the best ability among cereals to tolerate salinity (David *et al*., 2014). Alluvial and loamy soils are suitable for this crop (Baijukya *et al*., 2006). Deep vertisols and rocky soils are not suitable, owing to poor drainage and low fertility (Corbeels *et al*., 2000). Finger millet is a fast growing cereal crop that reaches maturity within three to six months and occasionally in only 45 days (David *et al*., 2014).

2.5 Establishment of finger millet

A feature of finger millet is its ability to adjust to different agro-climatic conditions (Thilakarathna and Raizada, 2015). According to Singh (2005), the quantity of seed required for direct row planting is from 8 to 10 kg ha^{-1}. Finger millet is usually sown during October or November, but sowing can be postponed up to the end of February to accommodate the late onset of the rainy season (Goron, 2017). However, sowing should be done early in rainfed areas to avoid moisture stress at critical stages of flowering. In areas where irrigation facilities are inadequate, the sowing should be done soon after onset of the first rains (Steduto *et al*., 2012).

Under rainfed conditions finger millet is sown in rows instead of broadcasting. An inter-row spacing of between 20 to 25 cm is recommended (Hegde and Gowda 1989). The seed should not be sown more than 3 to 4 cm deep (Rowell, 2014). Finger millet seeds can be broadcast or sown in rows after prior ploughing and weeding, as the crop is particularly weed-sensitive (Brown, 2017). Finger millet can be planted alone or intercropped with companion cereals, pulses and vegetables. It can also be planted as the first crop in a rotation system (Nene, 2006).

2.6 Water requirements of finger millet

Water is one of the essential inputs for crop production. It affects crop performance not only directly but also indirectly by influencing nutrient availability, timing of cultural operations, and other factors. Frequent irrigations provide adequate soil moisture during critical stages like crown root initiation, maximum tillering, late jointing, flowering and milk stage. According to Fageria and Baligar (2005), under rainfed conditions, finger millet straw yield was about 2 to 3 t ha^{-1} and reached 6 to 10 t ha^{-1} under irrigation. Reddy *et al*., (2003) further reported that, fresh weight yields of finger millet ranges from 8.3 t ha^{-1} under rainfed to 18.4 t ha^{-1} with 56 mm of irrigation. Greater benefits were observed from splitting the same quantity of irrigation water into more frequent irrigations (Beltrán, 1999). According Bhattarai *et al*., (1998), increased dry matter yields were obtained by irrigating every seven days instead of each 15 days.

Reddy *et al*., (2003) further suggested that, for finger millet, irrigating at a water: cumulative pan evaporation (IW: CPE) ratio of 10 (equivalent to 11 irrigations) is essential for maximum stover yields. Irrigating once or twice at tillering stage and then at flowering, resulted in high stover yields (Ceesay *et al*., 2006). However, irrigation at tillering and flowering will improve yields if long dry spells are experienced. During the dry season, the crop requires two to three irrigations, coinciding with tillering, flowering and grain filling stages (Wassmann *et al*., 2009). However, if transplanted, it requires irrigation for the first three days after planting (Wassmann *et al*., 2009).

2.7 Fertilization and weed management of finger millet

Finger millet responds well to nitrogen (N) application (Thilakarathna and Raizada 2015). Since many of the soils in the semi-arid regions are deficient in Nitrogen (Steduto *et al*., 2012). Acording to Thilakarathna and Raizada (2015), studies concerning N management in finger millet are mainly focused on the amount of N applied, timing of application, and varietal responses to N. Increases in yield and grain protein content in finger millet due to N fertilizer application rates of up to 40 kg N ha^{-1} was reported in Andhra Pradesh, India. The authors reported that the economic optimum rate of N fertilizer for finger millet was 43.5 kg N ha^{-1} under rainfed conditions (Thilakarathna and Raizada 2015).

Hegde and Gowda (1985) reported that finger millet grain yield was 23.1 kg ha^{-1} at 20 kg N ha^{-1}, while the yield benefit declined to 19.9 kg ha^{-1} at 60 kg N ha^{-1}. These results suggest that application of the correct rate of N fertilizer is important in order to maximize the profits of poor finger millet farmers (Thilakarathna and Raizada 2015). It is also important to note that the application of inorganic N fertilizer can delay flowering and physiological maturity by 1 to 2 weeks which can affect the final yield (De Valença *et al*., 2017).

The study also found that application of inorganic N alone (22.5 to 45 kg N ha^{-1}) did not increase the grain yield compared to the no fertilizer application under conditions of seed broadcasting and row planting. Therefore, was claimed that N application alone is not economical in finger millet cultivation (De Valença *et al*., 2017). Based on a long-term field experiment with finger millet, they found that continuous application of inorganic N fertilizer alone reduced the soil organic carbon level due to low dry matter production and reduced return of crop residues to the field. In addition to the amount of N supplied, the timing of N application is also important for finger millet (Bationo *et al*., 2007).

The importance of applying N starts with seed germination, a challenge for small seed crops like finger millet especially under nutrient deficient conditions (Thilakarathna and Raizada 2015). The application of inorganic N fertilizer at the time of planting stimulates better crop emergence especially in N deficient soil. Was also reported that incorporation of N fertilizer during seeding enhanced finger millet yield by 30% compared to broadcasted fertilizer. Synchronizing N supply with crop N demand is essential to maximize yield and N use efficiency (Cassman *et al*., 1993). Manyawu *et al*. (2003) reported that application of N on sandy loam soils at 50 kg ha^{-1} produced a finger millet grain yield of 2430 kg ha^{-1} when applied at planting, whereas the yield increased to 2650 kg ha^{-1} when the application time was split (at planting and 25 to 30 days after planting). Therefore, split application of N fertilizer enhances finger millet yield production and possibly reduces N losses as well (Fageria and Baligar 2005).

Weeds are a serious threat to finger millet, especially during the first three weeks after sowing (Haussmann *et al*., 2012). Where finger millet is sown in rows, weeding or hoeing at 15 days' intervals, starting from 25 days after sowing, are necessary (Kabaki *et al*., 2004). Alternatively, two to three inter-row mechanical cultivations can be done (Vanhala *et al*, 2004). Applying 2, 4-D at 0.75 kg ha-1, as a post-emergent spray 20 to 25 days after sowing, can control broad-leaved weeds (Haji, 2001). Alternatively, Isoproturon at 0.5 kg ha^{-1} as a pre-emergence spray is also effective. Oxyflurofen at

0.1 L t ha^{-1} as a pre-emergence herbicide can also be used to control weeds (Reddy, 2014).

2.8 Yield of finger millet

Little attention has been given to improve finger millet as a forage crop, especially in Africa, which is evident from the scarcity of literature and poor productivity of the crop (Handschuch and Wollni 2016). Due to the little research effort on this crop, the grain yield of finger millet in Kenya is low; ranging between 500 and 750 kg ha^{-1} (Oduori, 2008). Slightly higher grain yields, ranging between 680 and 1000 kg ha^{-1} have been reported in Uganda and in India under rainfed conditions (Yelevielbayire, 2017).

Although the crop is generally not grown under irrigation in sub-Saharan Africa, in India the average biomass yield of 2000 kg ha^{-1} under irrigation has been reported (Oerke and Dehne 2004). However, this is still below the biomass production potential of the crop; which is 6000 kg ha^{-1} under irrigation and 5000 kg ha^{-1} under rainfed conditions (Oduori, 2008). In different countries, biomass production potential of finger millet has been estimated at 4265 kg ha^{-1} in Uganda, 6060 kg ha^{-1} in Zimbabwe, 3700 kg ha^{-1} in Ethiopia and 4789 kg ha^{-1} in India (Oduori, 2008). Forage yield of finger millet under irrigated conditions are nearly double compared to those in rainfed conditions and varies from 4400 to 8800 kg ha^{-1} under irrigation (Muoni, 2019). Under high input-intensive management, finger millet yields can exceed 15000 kg ha^{-1}, which is reported in the Punjab state of India, where finger millet is grown for silage under irrigation and three cuttings are taken annually (Lubadde, 2014).

2.9 Nutritional value of finger millet

Nutritionally, finger millet is a good source of nutrients, especially of calcium, other minerals and fibre (Jukanti *et al*., 2016). The total carbohydrate content of finger millet has been reported to be in the range of 72 to 79.5% with starch as the main constituent (59.4 to 70.2%) (Rao *et al*., 2016). Singh and Raghuvanshi (2012) reported that non-starch polysaccharides account for 20 to 30% of the total carbohydrates in finger millets. Singh and Raghuvanshi (2012) further reported reducing sugars in the range of 1.2 to 1.8% and of 1.5% for reducing sugars and 0.03% for non-reducing sugars in vitro starch digestibility (IVSD) of native finger millet as 71.67%. Ramulu and Rao

(1997) reported total dietary fibre (TDF), insoluble dietary fibre (IDF), and soluble dietary fibre (SDF) contents in finger millet to be 12, 11 and 2%, respectively. Kamath and Belavady (1980) found 18.6% dietary fibre and 3.6% crude fibre while Joshi and Katoch (1990) reported 3.7% crude fibre in finger millet.

Finger millet has nearly 7.0 % protein but large variations in protein content, from 5.6 to 12.70%, have been reported (Chilkawar, 2017). The quality of protein is mainly a function of its essential amino acids (Upadhayay and Vishwa 2014). Finger millet contains 44.7% essential amino acids (Mbithi *et al*., 2000), which is higher than the 33.9% essential amino acids in protein of wheat. It contains the following important amino acids: isoleucine, leucine, methionine (an essential amino acid lacking in most food grains), phenyl alanine tryptophan, thereonine and valine (Onyango, 2016). These amino acids are often absent in starch-based diets of some subsistence farmers (Goron and Raizada 2015). The crude fat content in finger millet has been reported in the range of 1.3 to 1.8% (Jukanti *et al*., 2016). A study by Onyango (2016) indicated that finger millet has a crude fibre value of 3.10%, a crude protein content of 10.28%, a zinc content of 0.22 mg/g, a potassium content of 14.19.0 mg/g and a sodium content of 6.86 mg/g. The plant also contains high levels of calcium, iron and manganese (Tripathi *et al*., 2014).

Finger millet as a grain crop is crucial for the diets of children, pregnant women and lactating mothers as well for the economy of marginal farmers (Gupta *et al*., 2017). Its grains are rich in protein, vitamins, minerals, fibre content and energy as compared to other cereals (Thapliyal and Singh 2015). Some genotypes of finger millet have been analysed to contain calcium as high as 450 mg/100g (Gupta *et al*., 2017) and hence, can be developed and used as preventive drugs against osteoporosis (Gupta *et al*., 2017). Its seed coat is rich in phytochemicals like dietary fibre and polyphenols and is also very high in minerals, especially calcium (Devi *et al*., 2014). Chethan and Malleshi (2007) showed up to 2.3 gallic acid equivalents in whole meal and up to 6.4 in the seed coat of finger millet grains. The seed coat also shows anti-cancer and anti-diabetic activities, mainly due to its high polyphenol content, that indicates anti-oxidant activity, and high fibre that promotes slow digestion and blood sugar stability (Devi *et al*., 2014). Therefore, finger millet has maintained high socio-economic importance in the context of subsistence farmers of the Indian and African semi-arid tropic regions (Copper *et al*., 2008).

Cattle and buffaloes maintained solely on millet can meet their energy requirement for maintenance and further improvement in intake. This includes supplementing the critical nutrients and adopting processing methodologies to enhance fibre utilization (McDowell, 1988). According to Derso (2009), concentrate supplementation at 20% of the dietary dry matter (DM) improves the intake of dry mater of finger millet straw. Furthermore, the additions of small amounts of specific bypass proteins like fish-meal or cotton seed-meal to straw diets also substantially improves the rumen fermentation and subsequently the production performance (Wadhwa and Bakshi 2017). One of the studies conducted by Sharma (2003) indicated that Urea ammoniation (4% in 100 litre of water) of finger millet straw has shown beneficial effects in the form of increased dry matter intake (25 to 30%), organic matter digestibility (10 to 15 units) and total digestible nutrients (10 to 15 units) and total digestible nutrients (10 to 12 units) as compared to untreated straw.

The digestibility of nutrients from the crop residues of finger millet is generally low and considered as poor quality roughage (Rufino *et al*., 2006). In spite of their low nutritive value, the use of straws and stovers for animal feeding together with the possibilities to improve their feeding value is a topic of top priority in the scientific community (Maqsood and Ali, 2007). Research Institutes (Bangalore in collaborating with AICRP on small millets, GKVK, Bangalore) clearly indicated that variation in the chemical composition and digestibility of straw exists due to genetic and management practices and the quality of straw can be manipulated to the advantage without any detrimental effect on grain yield (Sunilgouda Shankaragouda, 2014).

Apart from the indigestible protein, the neutral detergent fiber is higher in finger millet, compared with that of maize and sorghum. These two factors possibly limit the use of finger millet as a complete substitute for maize in the diet of monogastric species such as pigs and poultry (Mutambuka, 2013). Finger millet has the potential to be an important forage crop in the dry land regions. Finger millet has superior forage quality in terms of nutritive value, mineral nutrients, lower lignin and better starch content, as compared to maize or sorghum (Zerbini and Thomas 2003). However, its biomass yield is lower than maize and sorghum in good soil, but has the potential for greater in poor soils with limited resources (Zegada-Lizarazu and Monti 2011).

2.10 The effect of cutting on finger millet

Yield is the manifestation of various physiological processes occurring in plants and these factors are usually modified by management practices (Mandal and Sinha 2004). Fodder yields vary greatly according to cultivation conditions. Cutting height is the major determinant of quantity and quality of stubble from which the sward will regrow in grasses. The energy for regrowth is supplied by carbohydrates is generated in the remaining photosynthetic tissue and non-structural carbohydrates stored in lower stems.

Finger millet intended for forage should be cut at vegetative stage (around 80 days after planting) for making good quality hay or silage (Njiru, 2010). When harvested 2 or 3 times during the growing season, it yielded 33 t ha^{-1} (Sampath, 1986). A study by Murray *et al*., (2008) indicated that increasing cutting interval significantly increased stem and total dry matter yields and significantly reduced the percentage of leaf, but has no effect on leaf dry matter production. Murray *et al*., (2008) further demonstrated that increasing cutting interval significantly reduced crude protein concentrations and increased ADF and NDF concentrations in stems and leaves.

2.11 Indicators of nutritional value used in this study

Neutral detergent fiber (NDF), acid detergent fiber (ADF) and crude protein (CP) are parameters that were used in this study to indicate forage quality (Van Soest, 1965).

2.11.1 Acid Detergent Fiber (ADF)

Acid Detergent Fiber represents the cell wall (fibrous) components of the plant material and includes cellulose, hemicellulose, lignin, cutin, silica and tannin content (Tainton, 1999). The term ADF is used because these components are partly soluble in acid. Acid detergent fiber percentages of fodder crops that range between 31 and 40% are classified as good to very good, between 41 and 42% as medium and when higher than 42%, as low in quality (Blezinger, 2002).

2.11.2 Neutral Detergent Fiber (NDF)

Neutral Detergent Fiber represents the cell content of the plant material and includes carbohydrates, starch, organic acids, pectin and protein (Tainton, 1999). These components are grouped as NDF because they are soluble in neutral detergents, such as water. Bodibe (2014) described forage with a NDF% of below 46% as very good, 47% to 60% as medium to good and above 61% as low in quality.

2.11.3 Crude protein (CP)

Crude protein is the measure of the nitrogen content in fodder. Because proteins consist of about 16% nitrogen by molecular weight, crude protein is computed by multiplying the nitrogen content of a food by 6.25, which is only an estimate of protein content, hence the term crude protein. Because feed can contain nitrogen-containing substances other than amino acids, measuring the nitrogen content is not an accurate method of measuring true protein. Ruminants can utilise most of the crude protein, while non-ruminants can only utilise the true protein portion of the crude protein. If the CP content of the pasture is above 13%, animals can maintain their weight and above 18% they will gain weight. However, if the CP content falls below 6 to 8%, appetite is depressed and the pasture intake by the animal will be decreased (Dannhauser, 1991).

2.12 Production constraints of finger millet

Small holder farmers in rural areas depend on crop residues to feed their livestock (Bebe *et al*., 2003). However, for farmers with less land, fodder production has to compete with production of food crops. In this case, a well-functioning fodder supply chain, combined with provision from the grain would constitute a solution (Wafula *et al*., 2017). While the crop is necessarily grown for grain, proper crop management and utilisation could help to optimise straw and stover production.

In many cases straw and stover yields from planted crops are low because of repeated harvesting, which depletes the soil of nutrients that are usually not replenished (Lorenz *et al*., 2010). This is usually coupled with inherently low soil fertility, especially Nitrogen and Phosphorous (Chapin, 1980). Population pressures have also led to a shortening of fallow periods, which in turn, has accelerated the decline in soil fertility (Dang *et al*., 2015). These processes have also prompted the expansion of finger millet into more marginal production areas in Africa (Gowda *et al*., 2008).

Further constraints include low and erratic rainfall, high temperatures, widespread *Striga* infestation, downy mildew and loss of grain to birds (Das and Rakshit 2016). Finger millet thrive under hot conditions, buts also tolerate cool climate (Todorov, 1988). A study conducted in Northern Ireland for evaluating finger millet as a forage crop revealed the problems with the photoperiod sensitivity in the crop (Sood and Babu 2016). The plant remained growing throughout the summer without flowering until it was killed by frost in early May (Leopold, 1970).

The small size of the seed is also a problem, making handling difficult (Oduori, 2008). Weeding, especially where grass weeds are concerned, is problematic. The problem is further compounded if seeds are broadcasted, where identification of grass weeds and the crop itself might prove difficult. Finger millet is also subject to bird damage, especially by *Quelea erthrops* (Rao, 2000). Although finger millet is rarely prone to diseases and insect damage, blast (a fungus infection caused by *Drechsera nodulosum*) can devastate the fields (Rao, 2000).

CHAPTER 3

3. METHODOLOGY AND ANALYTICAL PROCEDURES

3.1 Experimental site

The study was conducted for two consecutive seasons (2017 and 2018) at the University of Limpopo experimental farm, commonly known as Syferkuil.

3.2 The syferkuil experimental farm

The SEF is situated approximately 10 km Northwest of Mankweng (290 71' S, 230 84' E) (Figure 3.1). It is 1 600 ha in size, accommodating 1300 ha grazing and 300 ha croplands (Ntsoane, 2019).

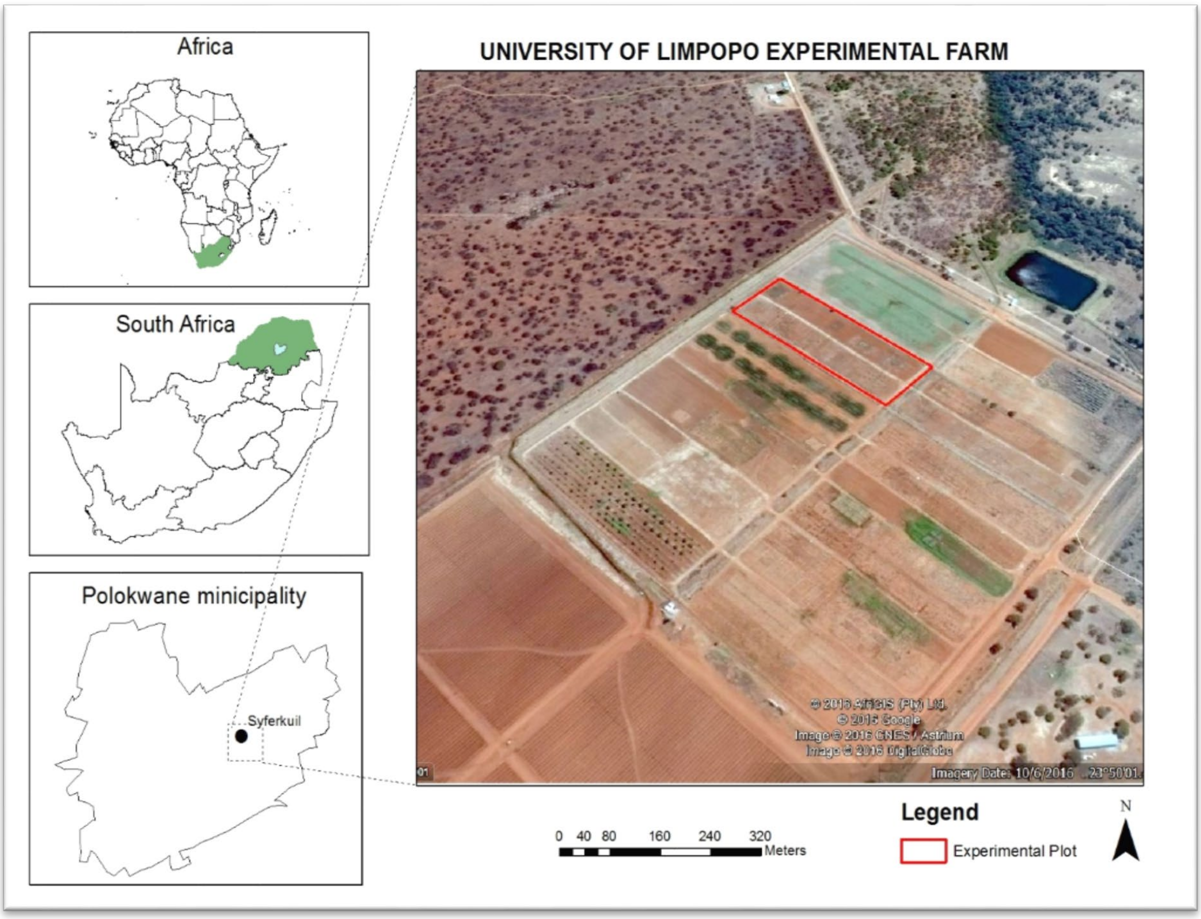


Figure 3.1: A map showing the location of the Syferkuil Experimental Farm (SEF).

3.2.1 Climate

The climate of the area is classified as semi-arid. The SEF is characterised by cool, dry winters and hot, arid summers (Table 3.1). The mean annual rainfall varies between 400 mm and 600 mm (with a mean of 468.5 mm) (Figure 3.2). Rainfall is erratic, with most rain occurring in the form of late afternoon thunderstorms mainly in summer. Summer minimum temperatures are relatively high (27.6°C - 27.5°C) and winter minimum temperatures can be cold (2.4°C - 2.5°C), with a mean summer temperature of 24.8ºC and a mean winter temperature of 10.2ºC. Incidences of frost occur (on average 8 days per year). (Table 3.1: South Afrian Weather Service, 2006).

Table 3.1: The long-term average meteorological data for the SEF, 2010-2018

Mont	Evap	FD	Rainmm	RHn%	RHx%	Sunshrs	Tmin°c	Tmax°c	Windkm
Jan	201.4	0.00	71.6	36.8	89.0	7.8	16.1	27.6	139.0
Feb	188.2	0.00	66.0	35.1	88.9	7.8	15.8	27.5	138.8
Mar	170.1	0.00	58,6	35.6	90.2	7.4	14.4	26.8	114.7
Apr	137.4	0.80	30.8	31.2	90.1	7.8	10.5	25.0	114.7
May	124.9	5.70	11.3	25.8	88.7	8.5	5.7	22.9	104.7
Jun	112.6	8.80	7.5	24.3	85.1	8.5	2.5	20.7	90.8
Jul	116.8	3.50	7.5	25.3	85.3	8.6	2.4	20.3	98.5
Aug	156.0	0.10	4.1	25.3	81.9	8.9	4.6	22.4	105.9
Sep	191.1	0.00	8.6	27.8	78.5	8.8	9.0	25.4	126.7
Oct	223.2	0.00	41.7	32.3	80.4	8.3	12.4	26.2	155.5
Nov	195.2	0.00	88.4	36.0	83.0	7.6	14.2	26.4	181.0
Dec	199.2	0.00	71.2	36.7	85.8	7.4	15.5	27.1	163.1
Total	2015.9	-	468.4	-	-	-	-	-	-

KEY NOTES

Average first frost: 10 June

Average last frost: 22 August

Average frost season: 74 days

Average frost day's year 1-20

Percentage years with frost: 100

Percentage years with frost: 100

Rain: rainfall mm month-1

FD days: frost days

Utot km day-1: wind run

Evap mm: A-Pan Evaporation

RHx %: Maximum Daily Relative Humidity

RHn % Minimum Daily Relative Humidity

Suns hours: Sunshine Hours

Tmax °c: Daily Maximum Temperature

Tmin °c: Daily Minimum temperature

3.2.2 Vegetation

The study area was situated in the Savanna Biome. According to Low and Rebelo (1996), the SEF falls broadly within the Sourish Mixed Bushveld, situated on the margin of the Polokwane Plateau Bushveld. The SEF is composed of elements of two overlapping vegetation types. These include the Polokwane Plateau Bushveld (flatter areas) and the Mamabolo Mountain Bushveld (mountainous areas). The Polokwane Plateau Bushveld varies from a dense, short bushveld to an open tree savanna with a well-developed grass layer (Mucina and Rutherford 2006).

The Mamabolo Mountain Bushveld consists of a combination of dense shrubby thickets and small trees of both *Vachellia* and *Senegalia* (*Acacia)* and broad-leaved species. The rock slabs or domes are sparsely vegetated, mostly with a mixture of xerophytes and several succulents (Low and Rebelo 1996). The area where the study was conducted was confined to the Polokwane Plateau Bushveld areas at the SEF. The dominant grasses are typical bushveld grasses such as *Aristida species*, *Panicum maximum* and *Themeda triandra*, while the woody component is dominated by *Vachellia* and *Senegalia* species such as *V. rehmanniana*, *V. habeclada* and *Dichrostachys cinerea* (Acocks, 1988).

3.2.3 Soils

The SEF varies in geology, which includes basement granite and gneiss, clastic sediments of the Pretoria Group (Vaalian) and ultramafic and mafic metavolcanics of the Pietersburg Group (Swazian). Shallow and skeletal soils (including Mispah and Glenrosa soil forms) occur (Soil Classification Working Group 1991). Land types are mainly Ib and Fa (Low and Rebelo 1996). The grey ferruginous lateritic soils are shallow and spread over the old granitic rock. Colluvial soils are found around the granitic outcrops, while alluvial soils are found in the river valley. These include soils of the Hutton form. Due to the size of the study area, it included various soil types at the sites that were used, namely Hutton, Glenrosa, Clovelly, Rocky, and Etosha types (Soil Classification Working Group, 1991). This study was conducted on a soil of the Hutton form.

3.3 Experimental layout and treatments

The experiment was arranged in a Randomized Complete Block Design (RCBD) with split plot arrangement having four replications. Irrigation was allocated to main plots whereas sowing method to subplots. Irrigation treatments consisted of two watering treatments (irrigation and rainfed), and two planting methods (broadcasting and row planting). Four treatment combinations were as follows (irrigation x broadcasting, irrigation x row planting, rainfed x broadcasting, rainfed x row planting) replicated four times to give a total of 16 plots. Sub-plots were 10 m^2 (2 m x 5 m) in size, with a 1 m alleyway in between.

Where row planting was concerned, 3 g of finger millet seeds were planted per plot, with an inter-row plant spacing of 25 cm, equalling a seedling rate of 10 kg ha^{-1}, as recommended by Shinggu *et al.* (2009). The experiments were planted on the 22 February 2017 and 21 February 2018. The plots were kept weed free manually throughout the period. In irrigated plots, 10 g of finger millet seeds broadcast by hand $plot^{-1}$, equalled a seedling rate of 10 kg ha^{-1}. Irrigated plots received 15 mm of water twice a week (30 mm per week) using sprinkler irrigation. Rainfed plots only received water only when it rained.

Seedbed preparations were carried out using a ripper as first action, followed by disc plough cultivation. To finish off, a disc harrow was used to create a fine seedbed. Before planting the equivalent of 150 kg ha^{-1} 2:3:4 (18) and 250 kg ha^{-1} organic fertilizer were applied and disced in. This organic fertilizer (OM = 650 kg m^{-3}) consists of chicken manure with 30 g kg^{-1} N, 30 g kg^{-1} K and 60 g kg^{-1} Ca. The following micro elements are included in this fertilizer: Sulphur 3.7 kg m^{-3}, Magnesium 4.5 g kg^{-1}, Zinc 235 mg kg^{-1}, Manganese 370 mg kg^{-1}, Copper 30 mg kg^{-1} and Iron 1255 mg kg^{-1}. Additional top dressing with N was applied in two portions, namely four weeks after establishment and again 8 weeks after planting. In each case 125 kg LAN (28%) was applied.

3.4 Sampling

To measure the effect of irrigation and planting method on the dry matter production of finger millet, the above-ground biomass was determined on a four weekly basis (March, April, May 2017 and 2018) by harvesting a 1 m^2 (1 m x 1 m) quadrate within each plot at a height of 3 cm above ground. All the material cut from each plot were oven dried at 55 ºC until it reached a constant weight. It was then weighed to determine the dry matter yield.

To quantify the nutritional value of finger millet, the dried samples of the April harvest were ground in a hammer mill to pass a 1-mm sieve and were send for analysis at the accredited Cedara feed laboratory of the KwaZulu Natal Department of Agriculture and Environmental Affairs, to determine the percentage NDF, ADF and crude protein.

3.5 Data analysis

Data was analysed, using the statistical program GenStat (Payne *et al*., 2009). Results were compared against each other by using analysis of variance and the Fisher's protected LSD at the 5% significance level.

CHAPTER 4

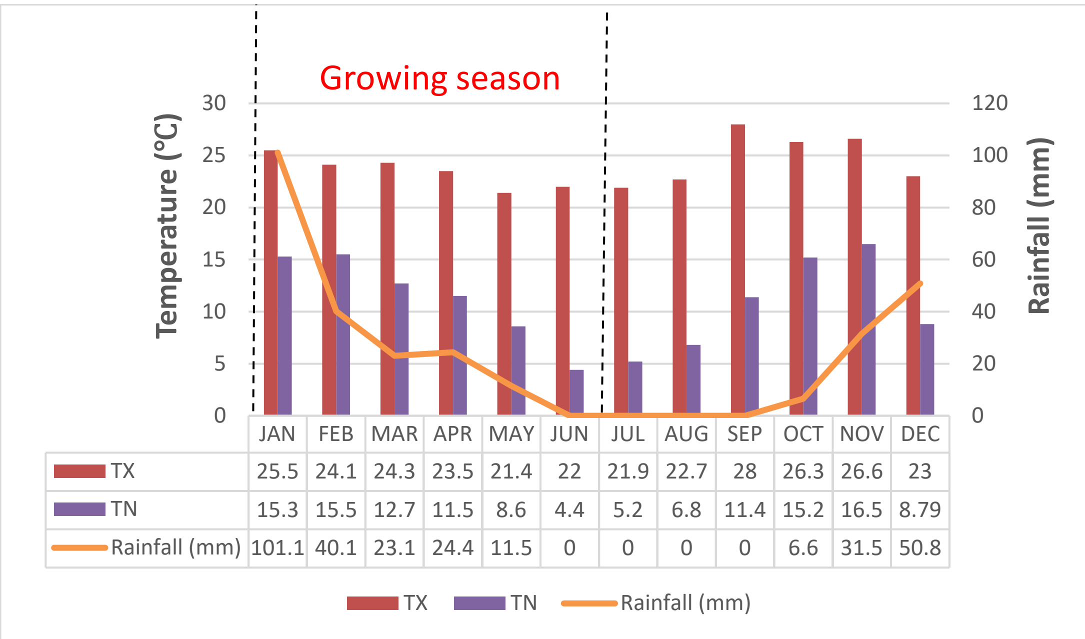
4. RESULTS

4.1 Climatic conditions of the study site during the growing season

Weather conditions of Syferkuil Experimental Farm (SEF 2017 and 2018)

Total monthly rainfall (mm), average maximum (Tx) and minimum (Tn) temperatures recorded during the growing season are presented in Figures 4.1 and 4.2 for 2017 and 2018 respectively. During the first season, the experiment was planted on the 22

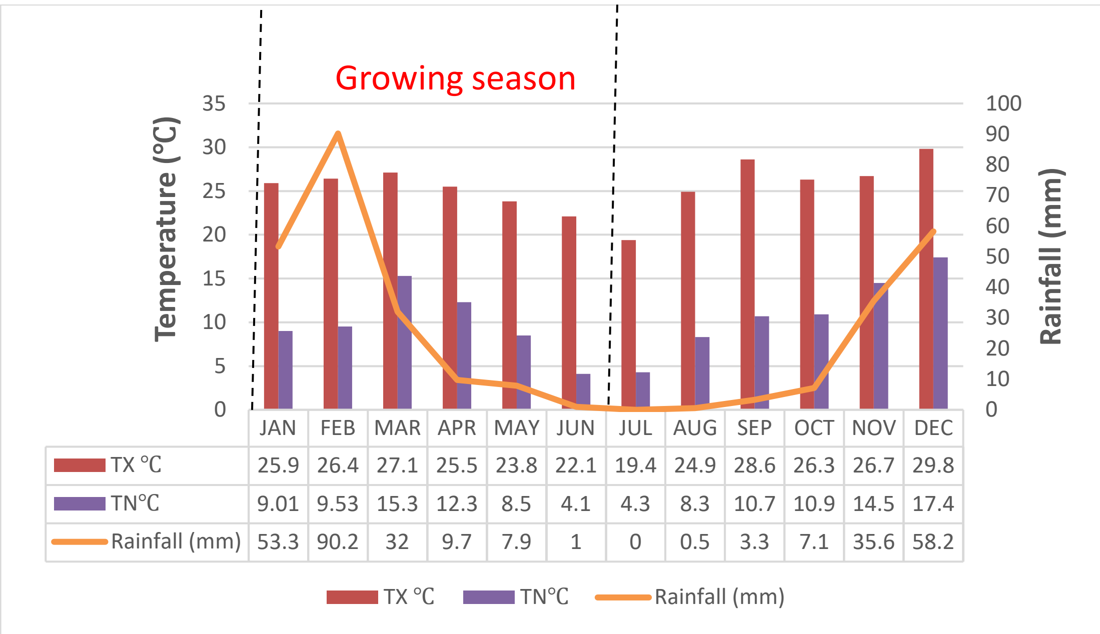
February 2017. February experienced a relatively cooler temperature with an average maximum of 24.1℃ and the average minimum temperature of 15.5 ℃. The recorded total rainfall during the growing season (from February to June) showed that SEF received relatively lower rainfall of 99.1 mm.



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TX	25.5	24.1	24.3	23.5	21.4	22	21.9	22.7	28	26.3	26.6	23
TN	15.3	15.5	12.7	11.5	8.6	4.4	5.2	6.8	11.4	15.2	16.5	8.79
Rainfall (mm)	101.1	40.1	23.1	24.4	11.5	0	0	0	0	6.6	31.5	50.8

Figure 4.1 Total monthly rainfall (mm), average maximum (Tx) and minimum (Tn) temperatures recorded during the 2017 growing season at SEF

In 2018 the experiment was planted on the 21 February 2018. February experienced a relatively cooler temperature with an average maximum of 26.4 ℃ and the average minimum temperature of 9.1 ℃ lower than the long- term average temperatures of 27.5 ℃ and 15.8 ℃ respectively. The recorded total rainfall during the growing season (from February to June) showed that SEF received relatively lower rainfall of 140.8 mm as compared to the long- term average of 166.7 mm on the same months.



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TX °C	25.9	26.4	27.1	25.5	23.8	22.1	19.4	24.9	28.6	26.3	26.7	29.8
TN°C	9.01	9.53	15.3	12.3	8.5	4.1	4.3	8.3	10.7	10.9	14.5	17.4
Rainfall (mm)	53.3	90.2	32	9.7	7.9	1	0	0.5	3.3	7.1	35.6	58.2

Figure 4.2 Total monthly rainfall (mm), average maximum (Tx) and minimum (Tn) temperatures recorded during the 2018 growing season at SEF

4.2 The effect of planting method on the dry matter production of finger millet under rainfed conditions in 2017 and 2018

The results on the dry matter accumulation of finger millet when planted in rows and broadcast under rainfed conditions in 2017, no seedling survived due to moisture stress. As indicated in the climatic results, the first growing season in which the experiment was conducted, was considerably drier than the long-term average, which ranged between 500-650 mm per annum. The 40.1 mm of rainfall recorded occurred early in the month while the crop was planted towards the end of February 2017. This was followed by a growing season where rainfall was well below the long-term annual average, resulting in zero production. Where germination occurred, seedlings did not survive the moisture stress. Hence, no dry matter production was recorded under rainfed conditions during the 2017 season.

The results on the dry matter accumulation of finger millet when planted in rows and broadcast under rainfed conditions in 2018 are reported in Figure 4.3. Data revealed that under rainfed conditions planting methods had no significant effect on the dry matter production ($P \leq 0.05$). The total dry matter production of finger millet under rainfed conditions in 2018 was 3371 kg ha^{-1} for row planting and 3770 kg ha^{-1} for broadcasting. The total dry matter production was achieved from the three cuts. Cut 1 produced 1826 kg ha^{-1} under row planting and 2222 kg ha^{-1} under broadcasting. The production for Cut 2 was 1268 kg ha^{-1} and 1312 kg ha^{-1} for row planting and broadcasting respectively. While Cut 3 produced 278 kg ha^{-1} and 235 kg ha^{-1} for row and broadcasting method respectively.

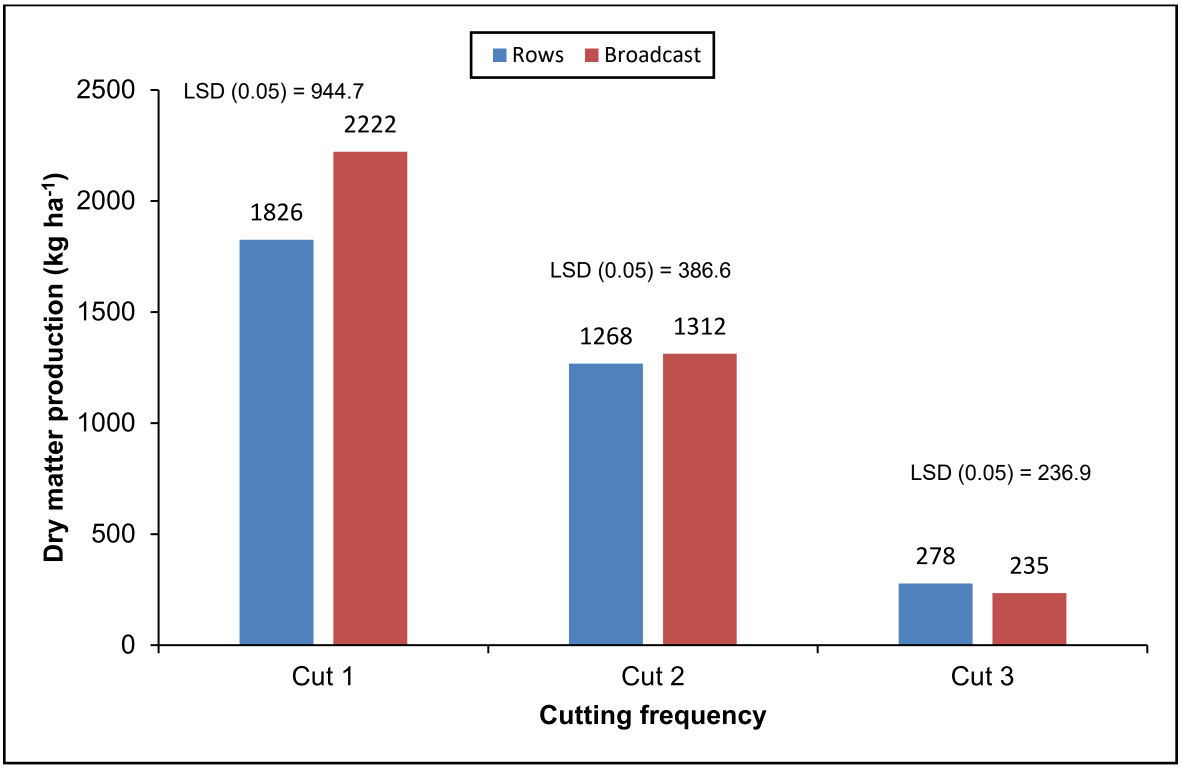


Figure 4.3: The effect of planting method on the dry matter production of finger millet over three cuts under rainfed conditions in 2018

4.3 The effect of planting method on the dry matter production of finger millet under irrigated conditions in 2017 and 2018

The effect of planting method on the dry matter production of finger millet under irrigation during the two growing seasons, 2017 and 2018 at SEF is presented in Figure 4.4 and 4.5. The results reveal that under irrigated condition, planting method had no significant effect on the dry matter production of finger millet ($P \leq 0.05$). The total dry matter production in the two growing season was achieved in three cuts per each season and the results are illustrated in Figure 4.4.

According to Figure 4.4, in 2017, when finger millet was planted in rows Cut 1 yielded the dry matter production of 3500 kg ha^{-1} which was 61.75% of the total dry matter production and 3245 kg ha^{-1} for broadcast, 63.35% of the total dry matter production. In 2018 Cut 1 under row planting produced the dry matter of 2605 kg ha^{-1}, 45.96% of the total production and 2145 kg ha^{-1} for broadcasting, 41.88% of the total production.

Cut 2 in 2017, produced 2012 kg ha^{-1}, 34.50% of the total production for row planting and 1638 kg ha^{-1} for broadcasting, contributing 31.50%, of the total production while in 2018, 1838 kg ha^{-1} was for obtained under row planting, 32.43% of the total production and1383 kg ha^{-1} for broadcasting, contributing 27.04%.

Cut 3 in 2017 under row planting produced 155 kg ha^{-1}, 2.73% of the total production and 240 kg ha^{-1} for broadcasting, 4.69%. The 2018 season yielded 1370 kg ha^{-1} under row planting and 1362 kg ha^{-1} under broadcast contributing 24.17% and 26.59% respectively.

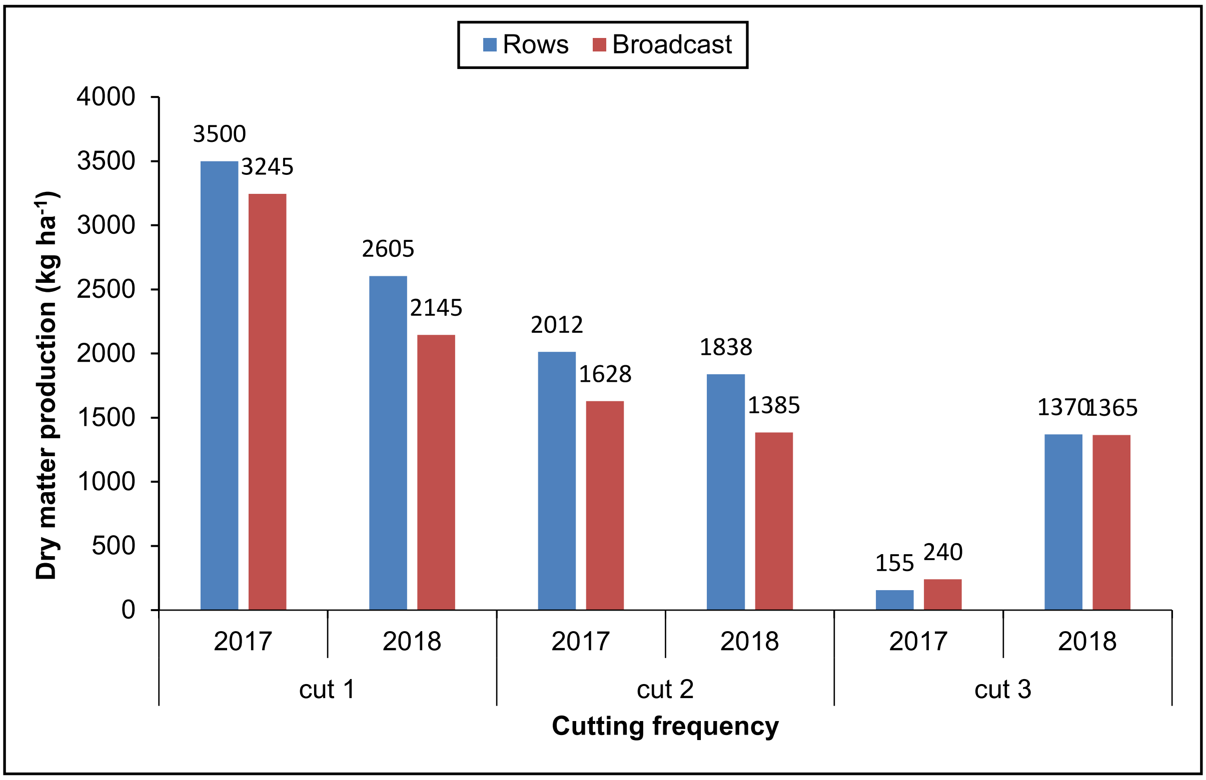


Figure 4.4: The effect of planting method on dry matter production of finger millet under irrigated conditions in 2017 and 2018

The effect of planting method on the total dry matter production of finger millet planted under irrigation for the two growing season is illustrated in Figure 4.5. According to Figure 4.5, although non-significantly different, in 2017, the total dry matter production was 5668 kg ha^{-1} and 5122 kg ha^{-1} under row planting and broadcast respectively. The 2018 season produced the total dry matter production of 5122 kg ha^{-1} under row planting and 4892 kg ha^{-1} when seeds were broadcasted.

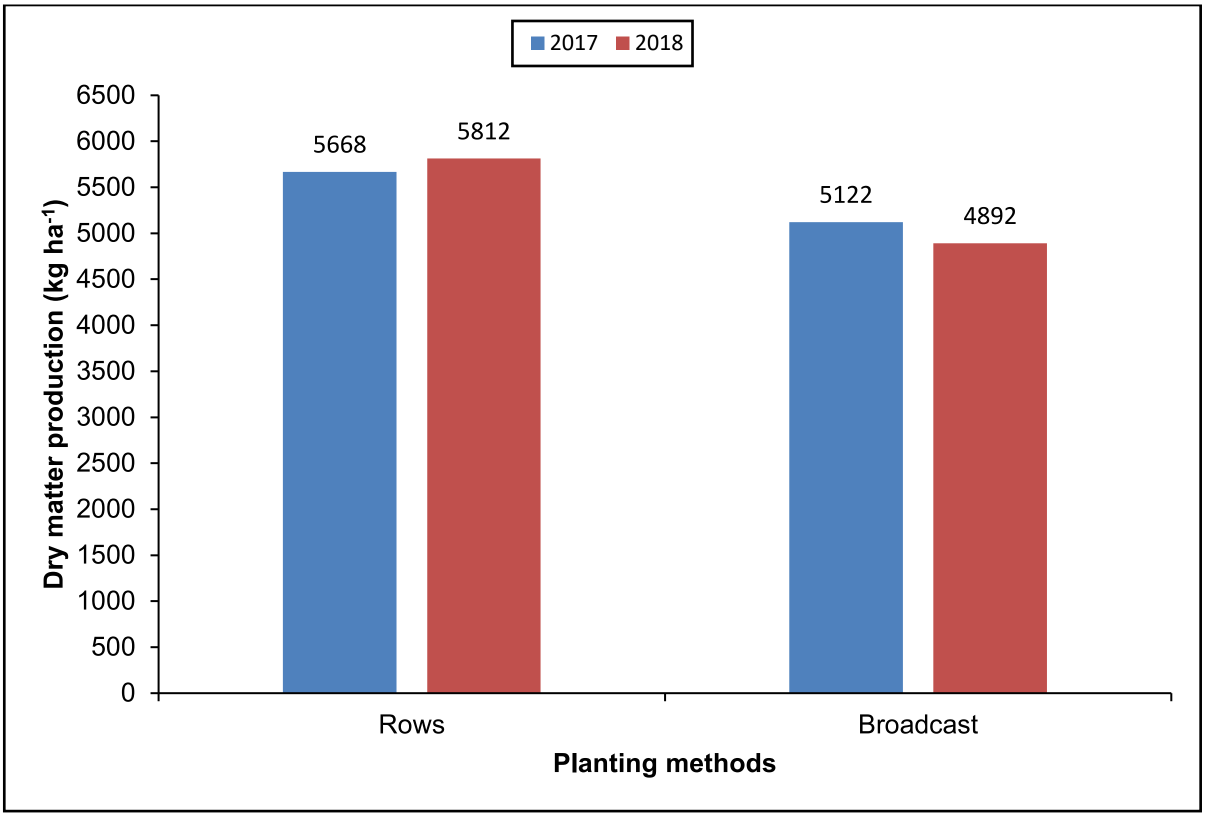


Figure 4.5: The effect of planting method on the total dry matter production of finger millet under irrigated conditions in 2017 and 2018

4.4 The effect of irrigation on the dry matter production of finger millet in 2018

The effect of irrigation on the dry matter production of finger millet during the 2018 growing season is presented in Figure 4.6. The results revealed that irrigation had a significant effect on the dry matter production of finger millet ($P \leq 0.05$).

The high total dry matter production was achieved under irrigation, in both rows and broadcasting treatments. The dry matter production of finger millet under irrigation and row planting was 5318 kg ha^{-1} (46.72% higher) compared to 3371 kg ha^{-1} produced under row planting under rainfed conditions. Broadcasting under irrigation produced

4890 kg ha^{-1}, which was 50.38 % higher than 3770 kg ha^{-1}, broadcasting under rainfed conditions.

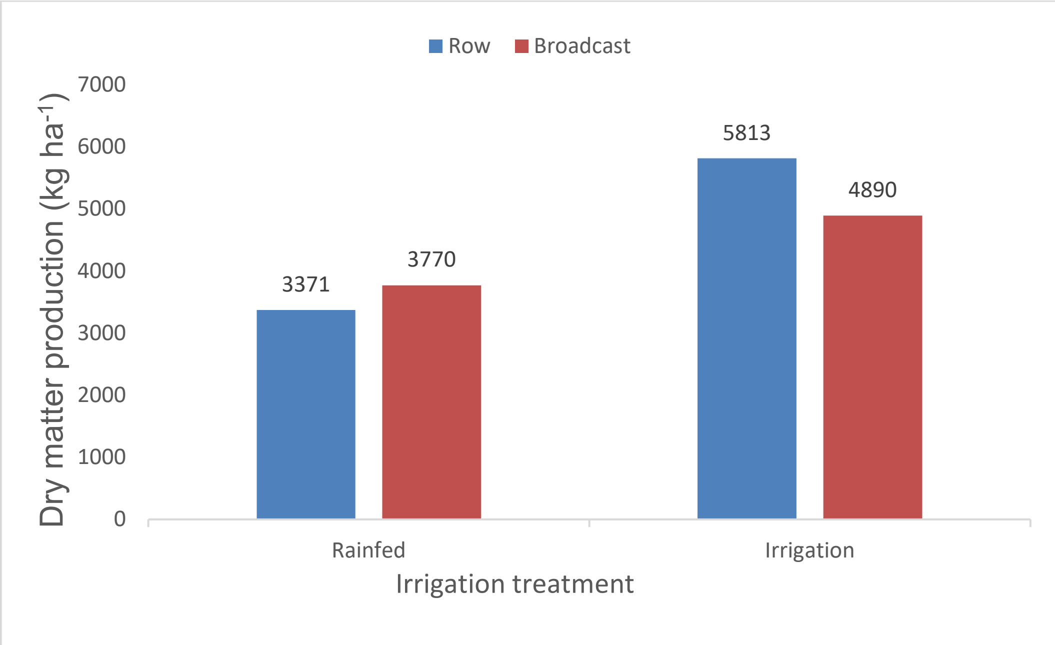


Figure 4.6: The total dry matter production of finger millet under rainfed and irrigated conditions in 2018

4.5 Interactive effects of irrigation treatment and planting method on the dry matter production of finger millet in 2018

The interactive effects of irrigation treatments and planting method on the dry matter production of finger millet as per cutting frequency during the 2018 growing season is been presented in Figure 4.7. The results revealed that the interactive effects of irrigation treatments and planting method had a significant influence ($P \leq 0.05$) on the dry matter production of finger millet at different cuts. According to Figure 4.7, Cut 1 yielded the dry matter production of 2605 kg ha^{-1} when planted in rows and 2145 kg ha^{-1} when broadcasted under irrigation. Under rainfed conditions and rows planting, the dry matter production was 1826 kg ha^{-1} and 2222 kg ha^{-1} when broadcasted.

For Cut 2 at SEF, row planting under irrigation produced 1838 kg ha^{-1}) 26.52% (and broadcasting and 31.43% (2135 kg ha^{-1}) of the total production. Row planting under rainfed conditions produced 37.61% (1268 kg ha^{-1}) and broadcasting 34.43% (1312 kg ha^{-1}) of the total production.

Row planting under irrigation produced 19.39% (1370 kg ha^{-1}) of the total production during Cut 3, while broadcasting produced 23.73% (1612 kg ha^{-1}) of the total production. Under rainfed conditions, row planting produced 8.24% (278 kg ha^{-1}) and broadcasting 6.97% (235 kg ha^{-1}) of the total production.

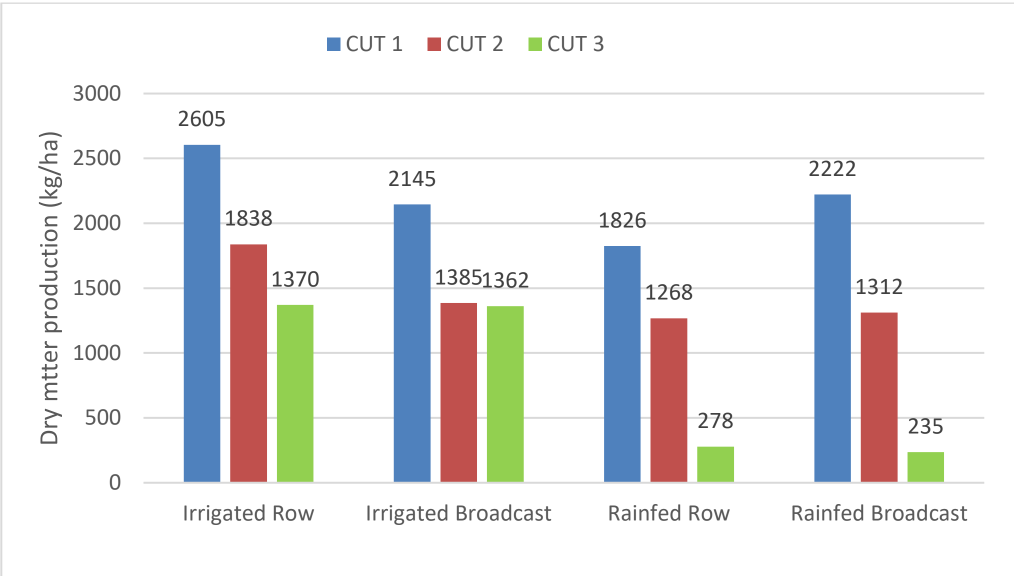


Figure 4.7: The dry matter production of finger millet over three cuts under rainfed and irrigated conditions in 2018

4.6 Nutritive value of finger millet

The forage nutritive value was determined from composite samples of all the four replications for each treatment in each season. The effect of irrigation treatments and planting method on the nutritive value of finger millet in 2017 and 2018 is depicted in Table 4.1.

Table 4.1: Nutritional value of finger millet under rainfed and irrigated conditions at SEF in 2017 and 2018

	Season	Watering	Planting method	CP%	ADF%	NDF%
SEF	2017	Irrigation	Row planting	15.85	31.53	82.14
			Broadcast	16.04	30.95	83.85
SEF	2018	Rainfed	Row planting	14.76	32.02	85.57
			Broadcast	16.87	30.54	84.07
		Irrigation	Row planting	11.88	30.99	84.23
			Broadcast	12.12	30.66	85.00

The results indicated in Table 4.1 revealed that the (Crude Protein) CP% of finger millet planted under irrigation in 2017 was 15.85% and 16.04% for row planting and broadcast respectively compared to 11.88% under row planting and 12.12% under broadcast in 2018. Finger millet planted under rainfed in rows at had the CP% of 14.76% and 16.87% when broadcasted. In all the treatments CP% was higher than 10%.

Reporting the interactive effects of irrigation and planting method on (Acid Detergent Fiber) ADF%, the results revealed that the ADF% was 32.02% under rainfed conditions and it ranged between 30.99% and 31.53% in 2017 and 2018 for row planting under irrigation. Furthermore, when broadcast the ADF% ranged between 30.54% and 30.95%. The (Neutral Detergent Fiber) NDF% under rainfed conditions was 85.57% and 84.07% for row planting and broadcast respectively compared to 82.14% for row planting and 83.85% for broadcast at under irrigation. Finger millet under irrigation had the NDF% of 82.14% and 85.00% when planted in rows and broadcast respectively. The NDF% varied between 82.15% and 85.57% which is classified as low in quality by Blezinger (2002). Irrigation treatments and planting methods did not influence the nutritive value of finger millet, because it remained within the same quality under all the treatments in the two seasons.

CHAPTER 5
5. DISCUSSIONS

5.1 Climatic conditions of the study sites

Based on the long-term average meteorological data, SEF receives summer rainfall, which is characterised by erratic and unpredictable seasonal distribution patterns (Figures 3.1 and 3.2). The rainfall treatment affected the dry matter production under rainfed conditions during the 2017 season. Due to low and erratic rainfall during the 2017 growing season no dry matter production was recorded. This highlighted the importance of the availability of soil moisture for the successful survival and biomass production of finger millet. In 2018, the good rainfall and its good distribution across the growing season supported adequate germination and production. An annual rainfall ranging from 500 to 1000 mm is suitable, provided it is well distributed across the growing season (David *et al*., 2014).

5.2 The effect of irrigation and planting methods on the dry matter production of finger millet

The total dry matter production of finger millet under rainfed conditions in 2018 was 3371 kg ha^{-1} for row planting and 3770 kg ha-1 for broadcasting. The total dry matter production of finger millet under irrigation and row planting was 5813 kg ha^{-1} (46.72% higher) compared to 3371 kg ha^{-1} produced under row planting under rainfed conditions. The results are in agreement with study of Reddy *et al.,* (2003) which reported the low fresh weight yields of finger millet ranging from 8.3 t ha^{-1}- with no irrigation to 18.4 t ha^{-1} with 56 mm of irrigation. According to Bhattarai *et al*., (1998), increased dry matter yields were obtained by irrigating every seven days instead of each 15 days. Another study by Yadav *et al.,* (2014) indicated that irrigated condition recorded significantly ($p< 0.05$) higher dry matter accumulation than rainfed condition of pearl millet. Water is one of the essential inputs for crop production. It affects crop performance not only directly but also indirectly by influencing nutrient availability, timing of cultural operations, and other factors.

Furthermore, the study also showed that planting methods had no significant effects on dry matter production under irrigated and rainfed conditions across the two seasons. According to Figure 4.5, in 2017, the total dry matter production was 5668 kg ha^{-1} and 5122 kg ha^{-1} under row planting and broadcast respectively. The 2018 season produced the total dry matter production of 5812 kg ha^{-1} under row planting and 4892 kg ha^{-1} when seeds were broadcasted. Although non-significantly different, the dry matter production of finger millet planted in rows was slightly above that achieved under broadcast. According to Samarajeewa *et al*., (2006) row planting of *Panicum maximum* was significantly better than broadcast planting only during the first 3 months of growth. Chauhdary *et al.*, (2015) concluded that row planting distribute seed uniformly at desired depth which provides appropriate depth for seed germination and crop establishment. Furthermore, it provides proper distance for optimum sunlight penetration for photosynthesis and proper depth to roots for uptake of water and soil nutrients resulted in good performance of the crop. The higher dry matter production of finger millet planted in rows may be due to the fact the seeds of finger millet under this method of planting had more space and nutrients which enhanced good and vigorous crop establishment when compared with broadcast. This is in line with the findings of Yoshida (1981) which showed that the number of tillers and panicles per square meter in a rice population are important function of planting methods which influences the distance between the plants.

5.3 The effect of irrigation and planting methods on the nutritional value of finger millet

The study revealed that treatments and planting methods had no significant effects on the nutritive value of finder millet in the two seasons. Table 4.1 revealed that the CP% of finger millet planted under irrigation in 2017 was 15.85% and 16.04% for row planting and broadcast respectively compared to 11.88% under row planting and 12.12% under broadcast in 2018. Finger millet planted under rainfed in rows had the CP% of 14.76% and 16.87% when broadcasted. In all the treatments CP% was higher than 10%. The findings of the study align with Gowda *et al.,* 2015 who reported the nutrient concentrations of crude protein CP (10.7%), Ca (1.20%), P (0.44%), K (4.53%) and Mg (0.31%) levels in the biomass of four finger millet accessions grown under dry land conditions in the semi-arid Texas High Plains. Gowda *et al*., (2015) reported that *E. coracana* has a crude protein content of 10.28%, a Zinc content of 0.22 mg/g, a potassium content of 14.19.0 mg/g and a sodium content of 6.86 mg/g. The NRC (2000) model for diet of beef cows suggests, 7% CP for maintenance in mid pregnancy, 9% for a beef cow in late pregnancy, and 11 to 13% CP for young (first parity) growing or mature lactating cows. In the present study, finger millet under all the treatments had adequate CP%, exceeded the 11% CP required by most beef cattle classes this requirement.

NDF is a predictor of voluntary intake because it provides bulk or fill, and ADF is the least digestible plant components including cellulose and lignin. In general, low NDF and ADF values are desired. The interactive effects of irrigation and planting method on NDF%, the results revealed that the ADF% was 33.02% under rainfed conditions and it ranged between 30.99% and 31.53% is 2017 and 2018 for row planting under irrigation. Blezinger (2002) indicated that Acid detergent fiber percentages of fodder crops that range between 31 and 40% are classified as good to very good, between

41 and 42% as medium and when higher than 42%, as low in quality. According to Blezinger (2002) the finger millet dry matter can be classified as good to very good in quality. The NDF of the dry matter in all the treatments was very high, it ranged between 80 and 86.64% with SEF 2018 rainfed the highest >86% ad SEF 2017 irrigation the lowest at <81%. According Blezinger (2002) the materials of finger millet in this study is descried as medium to low in quality.

CHAPTER 6

6. CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This chapter provides conclusions and recommendations based on the results of the study. The limitations and areas for further research are also discussed in this chapter.

6.2 Conclusions

Finger millet has the ability to adjust to different agro-climatic conditions, and once adequate moisture is available (minimum water requirement of 400 mm) and the temperature is above 15 °C, finger millet can produce adequate biomass (Mohamed *et al*., 2002). Irrigation had a significant effect on the dry matter production of finger millet ($P \leq 0.05$) in both seasons, therefore the hypothesis of the study is rejected. The results of the study revealed that low soil moisture, rainfall is detrimental to the crop biomass yield.

The results of the study showed that irrigation and planting methods had no significant effects on the nutritive value of finger millet in the two seasons, therefore the hypothesis of the study is accepted. Finger millet had CP% higher than 10% in all the treatments and both seasons, as per the NRC (2000) model, it is sufficient to sustain high producing beef cattle. ADF% range between 30.54 and 31.53%, according to Blezinger, (2002) which classified fodder with ADF% ranging between 31 and 40% as good to very good, it can be concluded that finger millet in this study produced fodder of good to very good quality. It can further be concluded that, good crop management practices is one of the pre-requisites for successful finger millet production. Based on this, farmers should be encouraged and motivated, using all the available avenues, to not only adopt but also practice modern farming techniques and inputs for increased productivity and profitability.

6.3 Recommendations

Further research needs to be focused on developing strategies for other agronomic management practices such as different planting dates and fertilization to improve the production of finger millet as a fodder crop in different regions of South Africa.

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APPENDIX A

STATISTICAL ANALYSES

APPENDIX A.1: Statistical analysis for the evaluation of Finger Millet at the SEF

Appendix A.1.1: Evaluation of finger millet under rainfed conditions (SEF, 2018)

Appendix A1.1.1: Analysis of variance of finger millet production under rainfed conditions for Cut 1 (SEF, 2018)

Table 1.1.1.1: Analysis of variance

Source of variation	d.f.	s.s.	m.s.	F	F pr.
Rep.subplot stratum					
Spacing	1	316012.	316012.	1.06	0.343
Residual	6	1788575.	298096.		
Total	7	2104588.			

Table 1.1.1.2: Tables of means

Variate: DM [1]

Grand mean 2024.

Spacing	Rows	Broadcast
	1825.a	2222.a

Table 1.1.1.3: Standard errors of means

Table	Spacing
rep.	4
d.f.	6
e.s.e.	273.0

Table 1.1.1.4: Least significant differences of means (5% level)

Table	Spacing
rep.	4
d.f.	6
l.s.d.	944.7

Table 1.1.1.5: Stratum standard errors and coefficients of variation

Variate: DM[1]

Stratum	d.f.	s.e.	cv%
rep.subplot	6	546.0	27.0

Table A1.1.2 Analysis of variance of finger millet production under rainfed conditions for Cut 2 (SEF, 2018)

Table 1.1.2.1: Analysis of variance

Source of variation	d.f.	s.s.	m.s.	F	F pr.
rep.subplot stratum					

Spacing	1	4050.	4050.	0.08	0.785
Residual	6	299550.	49925.		
Total	7	303600.			

Table 1.1.2.2: Tables of means

Variate: DM[2]

Grand mean 1290.

Spacing	Rows	Broadcast
	1268.a	1329.a

Table 1.1.2.3: Standard errors of means

Table	Spacing
rep.	4
d.f.	6
e.s.e.	111.7

Table 1.1.2.4: Least significant differences of means (5% level)

Table	Spacing
rep.	4
d.f.	6
l.s.d.	386.6

Table 1.1.2.5: Stratum standard errors and coefficients of variation

Variate: DM[2]

Stratum	d.f.	s.e.	cv%
rep.subplot	6	223.4	17.3

Table A1.1.3 Analysis of variance of finger millet production under rainfed conditions for Cut 3 (SEF, 2018)

Table 1.1.3.1: Analysis of variance

Source of variation	d.f.	s.s.	m.s.	F	F pr.
rep.subplot stratum					
Spacing	1	3741.	3741.	0.20	0.671
Residual	6	112437.	18739.		
Total	7	116178.			

Table 1.1.3.2: Tables of means

Variate: DM[3]

Grand mean 257.

Spacing	Rows	Broadcast
	278.a	235.a

Table 1.1.3.3: Standard errors of means

Table	Spacing
rep.	4
d.f.	6
e.s.e.	68.4

Table 1.1.3.4: Least significant differences of means (5% level)

Table	Spacing
rep.	4
d.f.	6
l.s.d.	236.9

Table 1.1.3.5: Stratum standard errors and coefficients of variation

Variate: DM[3]

Stratum	d.f.	s.e.	cv%
rep.subplot			

6	136.9	53.3

Table A1.1.4: Analysis of variance of finger millet production under rainfed conditions over three cuts (SEF, 2018)

Table 1.1.4.1: Analysis of variance

Source of variation	d.f.	s.s.	m.s.	F	F pr.
rep.subplot stratum					
Spacing	1	318801.	318801.	0.74	0.422
Residual	6	2572607.	428768.		
Total	7	2891408.			

Table 1.1.4.2: Tables of means

Variate: TotalDM

Grand mean 3570.

Spacing	Rows	Broadcast
	3371.a	3770.a

Table 1.1.4.3: Standard errors of means

Table	Spacing
rep.	4
d.f.	6
e.s.e.	327.4

Table 1.1.4.4: Least significant differences of means (5% level)

Table	Spacing
rep.	4
d.f.	6
l.s.d.	1133.0

Table 1.1.4.4: Stratum standard errors and coefficients of variation

Variate: TotalDM

Stratum	d.f.	s.e.	cv%

rep.subplot	6	654.8	18.3

DATA:

Season	rep	Spacing	Watering	DM [1]	DM[2]	DM[3]	Total DM
2018	1	Rows	Rainfed	1400	1600	400.0	3400
2018	1	Broadcast	Rainfed	2000	1200	150.0	3350
2018	2	Rows	Rainfed	2300	1150	123.0	3573
2018	2	Broadcast	Rainfed	3000	1650	360.0	5010
2018	3	Rows	Rainfed	1450	1150	450.0	3050
2018	3	Broadcast	Rainfed	2350	1200	240.0	3790
2018	4	Rows	Rainfed	2150	1170	140.0	3460
2018	4	Broadcast	Rainfed	1540	1200	190.0	2930

APPENDIX A.1.2: Statistical analysis for the evaluation of finger millet under irrigated conditions (SEF, 2017 and 2018)

Appendix A1.2.1: Analysis of variance of finger millet production under irrigated conditions for Cut 1 (SEF,2017 and 2018)

Table 1.2.1.1: Analysis of variance

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
season stratum					
Season	1	3980025.	3980025.		
season.rep.subplot stratum					
Spacing	1	511225.	511225.	0.29	0.600
Season.Spacing	1	42025.	42025.	0.02	0.880
Residual	12	21140500.	1761708.		
Total	15	25673775.			

Table 1.2.1.2: Tables of means

Variate: DM[1]

Grand mean 2874.

Season	2017	2018
	3372.	2375.

Spacing	Rows	Broadcast
	3052.	2695.

Season	Spacing	Rows	Broadcast
2017		3500.	3245.
2018		2605.	2145.

Table 1.2.1.3: Standard errors of means

Table	Season	Spacing	Season Spacing
rep.	8	8	4
d.f.	*	12	*
e.s.e.	*	469.3	663.6

Table 1.2.1.4: Least significant differences of means (5% level)

Table	Season	Spacing	Season Spacing
rep.	8	8	4
d.f.	*	12	*
l.s.d.	*	1446.0	2044.9

Table 1.2.1.5: Stratum standard errors and coefficients of variation

Variate: DM[1]

Stratum	d.f.	s.e.	cv%
season	0	*	*
season.rep.subplot	12	1327.3	46.2

Appendix A1.2.2: Analysis of variance of finger millet production under rainfed conditions for Cut 2 (SEF,2017 and 2018)

Table 1.2.2.1: Analysis of variance

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
season stratum					
Season	1	182756.	182756.		
season.rep.subplot stratum					
Spacing	1	684756.	684756.	1.54	0.238
Season.Spacing	1	6006.	6006.	0.01	0.909
Residual	12	5331325.	444277.		
Total	15	6204844.			

Table 1.2.2.2: Tables of means

Variate: DM[2]

Grand mean 1718.

Season	2017	2018
	1825.	1611.

Spacing	Rows	Broadcast
	1925.	1511.

Season	Spacing	Rows	Broadcast
2017		2012.	1638.
2018		1838.	1385.

Table 1.2.2.3: Standard errors of means

	Season	Spacing	Season.Spacing
rep.	8	8	4
d.f.	*	12	*
e.s.e.	*	235.7	333.3

Table 1.2.2.4: Least significant differences of means (5% level)

	Season	Spacing	Season Spacing
rep.	8	8	4
d.f.	*	12	*
l.s.d.	*	726.1	1026.9

Table 1.2.2.5: Stratum standard errors and coefficients of variation

Variate: DM[2]

Stratum	d.f.	s.e.	cv%
season	0	*	*
season.rep.subplot	12	666.5	38.8

Appendix A1.2.3: Analysis of variance of finger millet production under rainfed conditions for Cut 3 (SEF,2017 and 2018)

Table 1.2.3.1: Analysis of variance

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
season stratum					
Season	1	5463906.	5463906.		
season.rep.subplot stratum					
Spacing	1	6006.	6006.	0.23	0.641
Season.Spacing	1	8556.	8556.	0.33	0.579
Residual	12	315175.	26265.		
Total	15	5793644.			

Table 1.2.3.2: Tables of means

Variate: DM[3]

Grand mean 782.

Season	2017	2018
	198.	1366.

Spacing	Rows	Broadcast
	762.	801.

Season	Spacing	Rows	Broadcast
2017		155.	240.
2018		1370.	1362.

TaBle 1.2.3.3: Standard errors of means

Table	Season	Spacing	Season Spacing
rep.	8	8	4
d.f.	*	12	*

e.s.e.	*	57.3	81.0

Table 1.2.3.4: Least significant differences of means (5% level)

Table	Season	Spacing	Season Spacing
rep.	8	8	4
d.f.	*	12	*
l.s.d.	*	176.6	249.7

Table 1.2.3.4: Stratum standard errors and coefficients of variation

Variate: DM[3]

Stratum	d.f.	s.e.	cv%
season	0	*	*
season.rep.subplot	12	162.1	20.7

Appendix A1.2.4: Analysis of variance of finger millet production under rainfed conditions over three cuts (SEF, 2017 and 2018)

Table 1.2.4.1: Analysis of variance

Variate: Total DM

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
season stratum					
Season	1	7225.	7225.		
season.rep.subplot stratum					
Spacing	1	2146225.	2146225.	0.57	0.465
Season.Spacing	1	140625.	140625.	0.04	0.850
Residual	12	45186500.	3765542.		
Total	15	47480575.			

Table 1.2.4.2: Tables of means

Variate: TotalDM

Grand mean 5374.

Season	2017	2018
	5395.	5352.

Spacing	Rows	Broadcast
	5740.	5008.

Season	Spacing	Rows	Broadcast
2017		5668.	5122.
2018		5812.	4892.

<u>Table 1.2.4.3: Standard errors of means</u>

	Season	Spacing	Season Spacing
rep.	8	8	4
d.f.	*	12	*
e.s.e.	*	686.1	970.3

<u>Table 1.2.4.4: Least significant differences of means (5% level)</u>

	Season	Spacing	Season Spacing
rep.	8	8	4
d.f.	*	12	*
l.s.d.	*	2114.0	2989.6

<u>Table 1.2.4.5: Stratum standard errors and coefficients of variation</u>

Variate: TotalDM

Stratum	d.f.	s.e.	cv%
season	0	*	*
season.rep.subplot	12	1940.5	36.1

<u>DATA:</u>

Season	rep	Spacing	Watering	DM [1]	DM[2]	DM[3]	Total DM
2018	1	Rows	Irrigation	2700	1150	1340.0	5190
2018	1	Broadcast	Irrigation	1500	1400	1300.0	4200
2018	2	Rows	Irrigation	4500	3150	1500.0	9150
2018	2	Broadcast	Irrigation	2900	1500	1300.0	5700
2018	3	Rows	Irrigation	1440	1300	1440.0	4180

2018	3	Broadcast	Irrigation	2800	1440	1750.0	5990
2018	4	Rows	Irrigation	1780	1750	1200.0	4730
2018	4	Broadcast	Irrigation	1380	1200	1100.0	3680
2017	1	Rows	Irrigation	2400	1600	210.0	4210
2017	1	Broadcast	Irrigation	2950	1650	120.0	4720
2017	2	Rows	Irrigation	6000	3250	100.0	9350
2017	2	Broadcast	Irrigation	1800	1300	320.0	3420
2017	3	Rows	Irrigation	2650	2100	200.0	4950
2017	3	Broadcast	Irrigation	4930	2000	310.0	7240
2017	4	Rows	Irrigation	2950	1100	110.0	4160
2017	4	Broadcast	Irrigation	3300	1600	210.0	5110

APPENDIX A.1.3: Statistical analysis evaluation of finger millet under rainfed and irrigation conditions (SEF, 2018)

Appendix A1.3.1: Analysis of variance of finger millet production under rainfed and irrigated conditions for Cut 1 (SEF, 2018)

Table 1.3.1.1: Analysis of variance

Source of variation	d.f.	s.s.	m.s.	F	F pr.
plot stratum					
Watering	1	8136756.	8136756.		
wplot.rep.subplot stratum					
Spacing	1	170156.	170156.	0.03	0.859
Watering.Spacing	1	1458056.	1458056.	0.28	0.606
Residual	12	62282775.	5190231.		
Total	15	72047744.			

Table 1.3.1.2: Tables of means

Variate: DM[1]

Grand mean 2737.

Watering	Rainfed	Irrigation
	2024.	3450.

Spacing	Rows	Broadcast
	2840.	2634.

Watering	Spacing	Rows	Broadcast
Rainfed		1825.	2222.
Irrigation		3855.	3045.

Table 1.3.1.3: Standard errors of means

	Watering	Spacing	Watering Spacing
rep.	8	8	4
d.f.	*	12	*
e.s.e.	*	805.5	1139.1

Table 1.3.1.4: Least significant differences of means (5% level)

	Watering	Spacing	Watering Spacing
rep.	8	8	4
d.f.	*	12	*
l.s.d.	*	2481.9	3509.9

Table 1.3.1.5: Stratum standard errors and coefficients of variation

Variate: DM[1]

Stratum	d.f.	s.e.	cv%
wplot	0	*	*
wplot.rep.subplot	12	2278.2	83.2

Appendix A1.3.2: Analysis of variance of finger millet production under rainfed and irrigated conditions for Cut 2 (SEF, 2018)

Table 1.3.2.1: Analysis of variance

Source of variation	d.f.	s.s.	m.s.	F	F pr.
wplot stratum					
Watering	1	1939056.	1939056.		
wplot.rep.subplot stratum					
Spacing	1	117306.	117306.	0.15	0.710
Watering.Spacing	1	63756.	63756.	0.08	0.783
Residual	12	9682125.	806844.		

Total	15	11802244.

Table 1.3.2.2: Tables of means

Variate: DM[2]

Grand mean 1638.

Watering	Rainfed	Irrigation
	1290.	1986.

Spacing	Rows	Broadcast
	1552.	1724.

Watering	Spacing	Rows	Broadcast
Rainfed		1268.	1312.
Irrigation		1838.	2135.

Table 1.3.2.3: Standard errors of means

	Watering	Spacing	Watering Spacing
rep.	8	8	4
d.f.	*	12	*
e.s.e.	*	317.6	449.1

Table 1.3.2.4: Least significant differences of means (5% level)

Table	Watering	Spacing	Watering Spacing
rep.	8	8	4
d.f.	*	12	*
l.s.d.	*	978.6	1383.9

Table 1.3.2.5: Stratum standard errors and coefficients of variation

Variate: DM [2]

Stratum	d.f.	s.e.	cv%
wplot	0	*	*

wplot.rep.subplot 12 898.2 54.8

Appendix A1.3.3: Analysis of variance of finger millet production under rainfed and irrigated conditions for Cut 3 (SEF, 2018)

Table 1.3.3.1: Analysis of variance

Source of variation	d.f.	s.s.	m.s.	F	F pr.
wplot stratum					
Watering	1	6097196.	6097196.		
wplot.rep.subplot stratum					
Spacing	1	39701.	39701.	0.77	0.396
Watering.Spacing	1	81653.	81653.	1.59	0.231
Residual	12	615912.	51326.		
Total	15	6834461.			

Table 1.3.3.2: Tables of means

Variate: DM [3]

Grand mean 874.

Watering	Rainfed	Irrigation
	257.	1491.

Spacing	Rows	Broadcast
	824.	924.

Watering	Spacing	Rows	Broadcast
Rainfed		278.	235.
Irrigation		1370.	1612.

Table1.3.3.3: Standard errors of means

Table	Watering	Spacing	Watering Spacing
rep.	8	8	4
d.f.	*	12	*
e.s.e.	*	80.1	113.3

Table1.3.3.4: Least significant differences of means (5% level)

Table	Watering	Spacing	Watering

			Spacing
rep.	8	8	4
d.f.	*	12	*
l.s.d.	*	246.8	349.0

Table1.3.3.5: Stratum standard errors and coefficients of variation

Variate: DM[3]

Stratum	d.f.	s.e.	cv%
wplot	0	*	*
wplot.rep.subplot	12	226.6	25.9

Appendix A1.3.4: Analysis of variance of finger millet production under and irrigated rainfed conditions over three cuts (SEF, 2018)

Table 1.3.4.1: Analysis of variance

Source of variation	d.f.	s.s.	m.s.	F	F pr.
wplot stratum					
Watering	1	45081153.	45081153.		
wplot.rep.subplot stratum					
Spacing	1	16706.	16706.	0.00	0.961
Watering.Spacing	1	447896.	447896.	0.07	0.802
Residual	12	81621157.	6801763.		
Total	15	127166911.			

Table 1.3.4.2: Tables of means

Variate: TotalDM

Grand mean 5249.

Watering	Rainfed	Irrigation
	3570.	6928.

Spacing	Rows	Broadcast
	5217.	5281.

Watering	Spacing	Rows	Broadcast
Rainfed		3371.	3770.
Irrigation		7062.	6792.

Table 1.3.4.3: Standard errors of means

Table	Watering	Spacing	Watering Spacing
rep.	8	8	4
d.f.	*	12	*
e.s.e.	*	922.1	1304.0

Table 1.3.4.4: Least significant differences of means (5% level)

Table	Watering	Spacing	Watering Spacing
rep.	8	8	4
d.f.	*	12	*
l.s.d.	*	2841.2	4018.1

Table 1.3.4.5: Stratum standard errors and coefficients of variation

Variate: TotalDM

Stratum	d.f.	s.e.	cv%
wplot	0	*	*
wplot.rep.subplot	12	2608.0	49.7

DATA:

Season	rep	Spacing	Watering	DM[1]	DM[2]	DM[3]	TotalDM
2018	1	Rows	Irrigation	2700	1150	1340.0	5190
2018	1	Broadcast	Irrigation	1500	4400	1300.0	7200
2018	2	Rows	Irrigation	9500	3150	1500.0	14150
2018	2	Broadcast	Irrigation	6500	1500	1300.0	9300
2018	3	Rows	Irrigation	1440	1300	1440.0	4180
2018	3	Broadcast	Irrigation	2800	1440	1750.0	5990
2018	4	Rows	Irrigation	1780	1750	1200.0	4730
2018	4	Broadcast	Irrigation	1380	1200	2100.0	4680
2018	1	Rows	Rainfed	1400	1600	400.0	3400
2018	1	Broadcast	Rainfed	2000	1200	150.0	3350
2018	2	Rows	Rainfed	2300	1150	123.0	3573

2018	2	Broadcast	Rainfed	3000	1650	360.0	5010
2018	3	Rows	Rainfed	1450	1150	450.0	3050
2018	3	Broadcast	Rainfed	2350	1200	240.0	3790
2018	4	Rows	Rainfed	2150	1170	140.0	3460
2018	4	Broadcast	Rainfed	1540	1200	190.0	2930

APPENDIX A.2: Statistical analysis on evaluation of finger millet under irrigated and rainfed conditions (SEF, 2018)

Appendix A.2.1: Evaluation of finger millet under rainfed and irrigated conditions (SEF, 2018)

Appendix A.2.1.1: Analysis of variance of finger millet production under irrigated and rainfed conditions for cut 1 (SEF, 2018)

Table 2.1.1.1: Analysis of variance

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
site stratum					
Site	1	10418471.	10418471.		
site.wplot stratum					
Watering	1	5830259.	5830259.		
Site.Watering	1	2622623.	2622623.		
site.wplot.rep.subplot stratum					
Spacing	1	470208.	470208.	0.18	0.679
Site.Spacing	1	10476.	10476.	0.00	0.951
Watering.Spacing	1	1272411.	1272411.	0.47	0.498
Site.Watering.Spacing	1	335995.	335995.	0.13	0.727
Residual	24	64402176.	2683424.		
Total	31	85362618.			

Table 2.1.1.2: Tables of means

Variate: DM[1]

Grand mean 2166.

Watering	Irrigation	Rainfed
	2593.	1739.

Spacing	Rows	Broadcast
	2288.	2045.

Site	Watering	Irrigation	Rainfed
Syferkuil		3450.	2024.

Site	Spacing	Rows	Broadcast
Syferkuil		2840.	2634.

Watering	Spacing	Rows	Broadcast
Irrigation		2914.	2272.
Rainfed		1661.	1818.

	Watering	Irrigation		Rainfed	
Site	Spacing	Rows	Broadcast	Rows	Broadcast
Syferkuil		3855.	3045.	1825.	2222.

Table 2.1.1.3: Standard errors of means

Table	Site	Watering	Spacing	Site Watering
rep.	16	16	16	8
d.f.	*	*	24	*
e.s.e.	*	*	409.5	*

Table	Site Spacing	Watering Spacing	Site Watering Spacing
rep.	8	8	4
d.f.	*	*	*
e.s.e.	579.2	579.2	819.1

Table 2.1.1.4: Least significant differences of means (5% level)

Table	Site	Watering	Spacing	Site Watering

rep.	16	16	16	8
d.f.	*	*	24	*
l.s.d.	*	*	1195.3	*

Table	Site Spacing	Watering Spacing	Site Watering Spacing
rep.	8	8	4
d.f.	*	*	*
l.s.d.	1690.5	1690.5	2390.7

Table 2.1.1.5: Stratum standard errors and coefficients of variation

Variate: DM[1]

Stratum	d.f.	s.e.	cv%
site	0	*	*
site.wplot	0	*	*
site.wplot.rep.subplot	24	1638.1	75.6

Appendix A.2.1.2: Analysis of variance of finger millet production under irrigated and rainfed conditions for cut 2 (SEF, 2018)

Table 2.1.2.1 Analysis of variance

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
site stratum					
Site	1	779688.	779688.		
site.wplot stratum					
Watering	1	1893945.	1893945.		
Site.Watering	1	351751.	351751.		
site.wplot.rep.subplot stratum					
Spacing	1	62570.	62570.	0.12	0.731
Site.Spacing	1	539501.	539501.	1.04	0.317
Watering.Spacing	1	20.	20.	0.00	0.995
Site.Watering.Spacing	1	124376.	124376.	0.24	0.628

Residual	24	12395544.	516481.
Total	31	16147393.	

Table 2.1.2.2: Tables of means

Variate: DM[2]

Grand mean 1482.

Watering	Irrigation	Rainfed
	1725.	1239.

Spacing	Rows	Broadcast
	1526.	1438.

Site	Watering	Irrigation	Rainfed
Syferkuil		1986.	1290.

Site	Spacing	Rows	Broadcast
Syferkuil		1552.	1724.

Watering	Spacing	Rows	Broadcast
Irrigation		1769.	1682.
Rainfed		1284.	1194.

	Watering	Irrigation		Rainfed	
Site	Spacing	Rows	Broadcast	Rows	Broadcast
Syferkuil		1838.	2135.	1268.	1312.

Table 2.1.2.3: Standard errors of means

Table	Site	Watering	Spacing	Site Watering
rep.	16	16	16	8
d.f.	*	*	24	*
e.s.e.	*	*	179.7	*

Table	Site Spacing	Watering Spacing	Site Watering Spacing
rep.	8	8	4
d.f.	*	*	*
e.s.e.	254.1	254.1	359.3

Table 2.1.2.4: Least significant differences of means (5% level)

Table	Site	Watering	Spacing	Site Watering
rep.	16	16	16	8
d.f.	*	*	24	*
l.s.d.	*	*	524.4	*

Table	Site Spacing	Watering Spacing	Site Watering Spacing
rep.	8	8	4
d.f.	*	*	*
l.s.d.	741.6	741.6	1048.8

Table 2.1.2.5: Stratum standard errors and coefficients of variation

Variate: DM[2]

Stratum	d.f.	s.e.	cv%
site	0	*	*
site.wplot	0	*	*
site.wplot.rep.subplot	24	718.7	48.5

Appendix A.2.1.3: Analysis of variance of finger millet production under irrigated and rainfed conditions for cut 3 (SEF, 2018)

Table 2.1.3.1: Analysis of variance

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
site stratum					
Site	1	1547920.	1547920.		
site.wplot stratum					
Watering	1	2301585.	2301585.		
Site.Watering	1	3900424.	3900424.		
site.wplot.rep.subplot stratum					
Spacing	1	3240.	3240.	0.11	0.742
Site.Spacing	1	50562.	50562.	1.73	0.201

Watering.Spacing	1	67344.	67344.	2.30	0.143
Site.Watering.Spacing	1	20910.	20910.	0.71	0.407
Residual	24	703056.	29294.		
Total	31	8595042.			

Table 2.1.3.2: Tables of means

Variate: DM[3]

Grand mean 654.

Watering	Irrigation	Rainfed
	922.	386.

Spacing	Rows	Broadcast
	644.	664.

Site	Watering	Irrigation	Rainfed
Syferkuil		1491.	257.

Site	Spacing	Rows	Broadcast
Syferkuil		824.	924.

Watering	Spacing	Rows	Broadcast
Irrigation		866.	978.
Rainfed		422.	350.

	Watering	Irrigation		Rainfed	
Site	Spacing	Rows	Broadcast	Rows	Broadcast
Syferkuil		1370.	1612.	278.	235.

Table 2.1.3.3: Standard errors of means

Table	Site	Watering	Spacing	Site Watering
rep.	16	16	16	8
d.f.	*	*	24	*
e.s.e.	*	*	42.8	*

Table	Site Spacing	Watering Spacing	Site Watering Spacing

rep.	8	8	4
d.f.	*	*	*
e.s.e.	60.5	60.5	85.6

Table 2.1.3.4: Least significant differences of means (5% level)

Table	Site	Watering	Spacing	Site Watering
rep.	16	16	16	8
d.f.	*	*	24	*
l.s.d.	*	*	124.9	*

Table	Site Spacing	Watering Spacing	Site Watering Spacing
rep.	8	8	4
d.f.	*	*	*
l.s.d.	176.6	176.6	249.8

Table 2.1.3.5: Stratum standard errors and coefficients of variation

Variate: DM[3]

Stratum	d.f.	s.e.	cv%
site	0	*	*
site.wplot	0	*	*
site.wplot.rep.subplot	24	171.2	26.2

Appendix A.2.1.4: Analysis of variance of finger millet production under irrigated and rainfed conditions for cut 2 (SEF, 2018)

Table 2.1.4.1: Analysis of variance

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
site stratum					
Site	1	28675164.	28675164.		
site.wplot stratum					

Watering	1	28173771.	28173771.		
Site.Watering	1	17535042.	17535042.		
site.wplot.rep.subplot stratum					
Spacing	1	772524.	772524.	0.21	0.653
Site.Spacing	1	1127251.	1127251.	0.30	0.587
Watering.Spacing	1	746642.	746642.	0.20	0.658
Site.Watering.Spacing	1	6786.	6786.	0.00	0.966
Residual	24	89340528.	3722522.		
Total	31	166377709.			

Table 2.1.4.1: Tables of means

Variate: TotalDM

Grand mean 4302.

Watering	Irrigation	Rainfed
	5241.	3364.

Spacing	Rows	Broadcast
	4458.	4147.

Site	Watering	Irrigation	Rainfed
Syferkuil		6928.	3570.

Site	Spacing	Rows	Broadcast
Syferkuil		5217.	5281.

Watering	Spacing	Rows	Broadcast
Irrigation		5549.	4932.
Rainfed		3367.	3361.

	Watering	Irrigation		Rainfed	
Site	Spacing	Rows	Broadcast	Rows	Broadcast
Syferkuil		7062.	6792.	3371.	3770.

Table 2.1.4.3: Standard errors of means

Table	Site	Watering	Spacing	Site Watering
rep.	16	16	16	8

d.f.	*	*	24	*
e.s.e.	*	*	482.3	*

Table	Site Spacing	Watering Spacing	Site Watering Spacing
rep.	8	8	4
d.f.	*	*	*
e.s.e.	682.1	682.1	964.7

Table 2.1.4.4: Least significant differences of means (5% level)

Table	Site	Watering	Spacing	Site Watering
rep.	16	16	16	8
d.f.	*	*	24	*
l.s.d.	*	*	1407.9	*

Table	Site Spacing	Watering Spacing	Site Watering Spacing
rep.	8	8	4
d.f.	*	*	*
l.s.d.	1991.0	1991.0	2815.7

Table 2.1.4.5: Stratum standard errors and coefficients of variation

Variate: TotalDM

Stratum	d.f.	s.e.	cv%
site	0	*	*
site.wplot	0	*	*
site.wplot.rep.subplot	24	1929.4	44.8

DATA:

Site	Season	rep	Spacing	Watering	DM[1]	DM[2]	DM[3]	TotalDM
Syferkuil	2018	1	Broadcast	Irrigation	1500	4400	1300.0	7200

Syferkuil	2018	2	Broadcast	Irrigation	6500	1500	1300.0	9300
Syferkuil	2018	3	Broadcast	Irrigation	2800	1440	1750.0	5990
Syferkuil	2018	4	Broadcast	Irrigation	1380	1200	2100.0	4680
Syferkuil	2018	1	Rows	Irrigation	2700	1150	1340.0	5190
Syferkuil	2018	2	Rows	Irrigation	9500	3150	1500.0	14150
Syferkuil	2018	3	Rows	Irrigation	1440	1300	1440.0	4180
Syferkuil	2018	4	Rows	Irrigation	1780	1750	1200.0	4730
Syferkuil	2018	1	Broadcast	Rainfed	2000	1200	150.0	3350
Syferkuil	2018	2	Broadcast	Rainfed	3000	1650	360.0	5010
Syferkuil	2018	3	Broadcast	Rainfed	2350	1200	240.0	3790
Syferkuil	2018	4	Broadcast	Rainfed	1540	1200	190.0	2930
Syferkuil	2018	1	Rows	Rainfed	1400	1600	400.0	3400
Syferkuil	2018	2	Rows	Rainfed	2300	1150	123.0	3573
Syferkuil	2018	3	Rows	Rainfed	1450	1150	450.0	3050
Syferkuil	2018	4	Rows	Rainfed	2150	1170	140.0	3460