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Water use efficiency of six rangeland grasses under varied soil moisture content levels in the arid Tana River County, Kenya

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This study evaluated water use efficiency (WUE) of six range grasses, namely; *Chloris roxburghiana, Eragrostis superba, Enteropogon macrostachyus, Cenchrus ciliaris, Chloris gayana*, and *Sorghum sudanense* grown at 80, 50, 30% field capacity (FC) soil moisture contents and rainfed treatment which represented water deficit conditions. The changes in soil moisture content were measured by Gypsum Block which aided in determining the irrigation schedules. The grasses demonstrated varied levels of WUE which was evaluated by amount of biomass productivity in relation to evapotranspired water during the growing period. The three soil moisture content treatments had higher water use efficiency than rainfed conditions. There was a declining trend in WUE with grass species maturity where *S. sudanense* had higher WUE at 8, 10 and 12th weeks (> 15 kg DM ha^{-1} mm^{-}) in all the treatments followed by *C. gayana* and *E. macrostachyus* and were significantly ($p<0.05$) different from *E. superba, C. ciliaris* and *C. roxburghiana* which had WUE less than 10 among the six grass species. The 30% FC soil moisture content had higher WUE at all the phenological stages for *S. sudanense, C. gayana* and *E. macrostachyus* compared to 80, 50% FC and rainfed with all having WUE greater than 20 kg DM ha^{-1} mm^{-1}. These three species are recommended for irrigated pasture establishment in semi-arid lands where water supply uncertainties exist, owing to their high water use efficiency under lower soil moisture levels.

Key words: Water use efficiency (WUE), water stress tolerance, range grasses, pasture irrigation, water deficit, Kenya.

INTRODUCTION

Water-use efficiency (WUE) is a critical consideration of plant productivity under water deficit environments (Blum, 2009). Under rainfed condition, WUE refers to rain water that is directly used by the plant during growth with higher value resulting in “more yield per drop” of rain water. Conversely, WUE under irrigation systems refer to plant

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productivity per amount of irrigation water supplied (Pereira et al., 2002). WUE is computed in two ways. One is the consideration of the amount of plant yields per unit volume of water used over given land area. The second one considers the amount of plant yields per unit of water that goes through evapotranspiration during growth (Caviglia et al., 2001; Garofalo and Rinaldi, 2013). The latter has a better representation of WUE in terms of accounting for the exact water used by the plant during photosynthesis and transpiration and was therefore, used in this study.

The increasing scarcity of water resource in the arid rangelands is further constrained by increasing human and livestock population which calls for plants with higher WUE (Rosegrant et al., 2002; Falkenmark, 2007). Practicing irrigation in the dry lands requires sustainable use of the scarce water availability to obtain adequate crop productivity (Pereira et al., 2002; Yang et al., 2006). This drives the research to maximize the WUE of the various cultivated crops especially in the dry rangelands, where climate change is exacerbating the negative effects of the water scarcity. Thus, adaptation of cropping systems which efficiently exploit the reduced water available for irrigation is important and must be encouraged (Falkenmark, 2007).

Livestock production in the arid rangelands of Kenya faces challenge of adequate forage supply due to the prevailing water deficit that reduces feed supply. There exist three options for an efficient utilization of available water to increase productivity in these areas: (i) increasing water productivity by reducing losses, (ii) improving the use of rainfall and expanding rainfed agriculture, and (iii) pursuing other water sources for pasture and crop production (Allan, 1997; WWC, 2004; Hoekstra and Hung, 2005; Falkenmark, 2007). These options may contribute to improvement of WUE, by reducing water losses and increasing productivity of pastures and crops in the arid rangelands. Innovative cropping systems involving cultivation of drought tolerant grass species with higher WUE and soil moisture preservation are promising interventions in the arid rangelands (Allan, 1997).

The challenge facing the farmers is determining how much water to apply during irrigation for optimized productivity of pastures, even more, when its supply is limited (Orloff et al., 2003). The other challenge is to avoid the water table raising and salinization of soil surface (Kitamura, et al., 2006). Proper irrigation is a critical aspect to improving and maintaining the crop productivity and at the same time to preserve water and soil nutrients (Celano et al., 2011). Determining when and how much to irrigate to attain the highest WUE is critical process in irrigated farming which drastically improve the crop performance (Kang'au et al., 2011).

The decision of when to irrigate is usually based on the past experiences or crop evapotranspiration or soil moisture measurements (Centeno et al., 2010; Naik et al., 2012). The use of past experiences for the irrigation management is not applicable in rangelands due to the climatic changes over the recent past. This has made use of experience difficult under established pastures where multiple harvests in a year or season are done compared to one season cropping systems. Irrigation timing and amounts to apply in pastures is critical and cannot be done close to harvest or curing phase (Playan and Mateos, 2006). The use of evapotranspiration method could lack in accuracy and reliability in the extensive fields with wide spatial-temporal variability (Playan and Mateos, 2006). Consequently, the most applicable irrigation scheduling techniques are soil based (Beetz and Rinehart, 2006) that involves the use of tension meters and gypsum blocks (electrical resistance blocks) to monitor the soil moisture dynamic (Wood and Finger, 2006). Such techniques help in determining appropriate time and amount of irrigation to achieve high WUE (Wood and Finger, 2006). The electrical resistance blocks technique provides a cost-effective methodology for improving irrigation management of growers (Gómez-del-Campo, 2013).

This study evaluated the WUE of *Chloris roxburghiana, Eragrostis superba, Enteropogon macrostachyus, Cenchrus ciliaris, Chloris gayana* and *Sorghum sudanense* at different growth stages under different ranges of soil water content to determine which species performs better at low moisture levels. These six species were chosen because they are the dominant species in the arid and semi arid environments of Kenya as well as in the spontaneous grazing fields in the studied area. These species have been promoted by the local policies as pasture crops in the Kenyan arid environments (Mganga et al., 2010).

MATERIALS AND METHODS

Study area

The research was carried out in Tana River County (Figure 1), within coordinates 1°30′S, 40°0′E, 1.5°S 40°E. The experimental study covered the period from September, 2012 to April, 2013. The experimental location was Bura Irrigation Scheme, in the Arid and Semi-arid Lands (ASALs) of Kenya. The area experiences frequent droughts which have precipitated conflicts between farmers and pastoralists over forage resources. This has necessitated the need for pasture production to reduce conflicts over pasture and water resources. The climate of the area is hot and dry with daily temperatures ranging between 20 and 38°C. Temperatures are highest between February and April and September to October. Rainfall has a bimodal distribution with long rains occurring in April-June and short rains in November-December. Long-term average rainfall ranges from 220 to 500 mm with erratic distribution. The County is divided into three livelihood zones; namely, pastoral, agro-pastoral (mixed farming) and marginal mixed farming.

The soil types are *Vertisols* which are clay-rich soils that shrink and swell with changes in moisture content. During dry periods, the

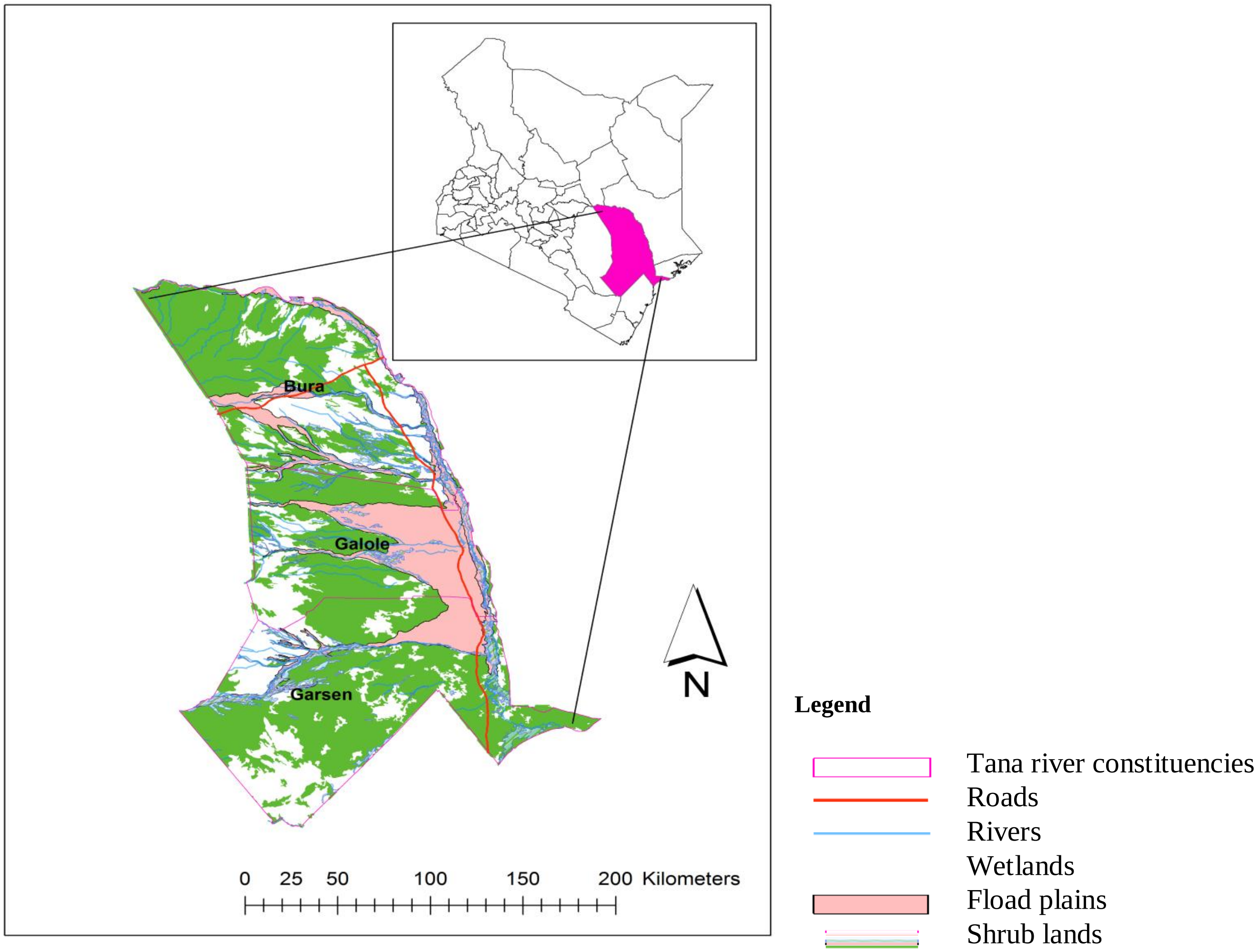

Figure 1. Study Area: Map of Kenya (top right) in relation to extract of Tana river county (below).

soil volume shrinks, and deep wide cracks develop. The soil volume then expands during wet seasons during soaking. The soils show low infiltration rates as a result of sealing by high clay content. Pastoralism and agropastoralism are the main economic activities in the study area, with two established National irrigation schemes, Hola and Bura, with the latter being the experimental study site. The two schemes were established by the Kenyan government in 1980's to increase food crop production. However, their location in the arid rangelands has necessitated the incorporation of pasture production to benefit the majority of pastoral communities in the area.

Experimental layout and design

One-acre parcel of land that was not cultivated during the previous season was identified within Bura irrigation scheme, National Irrigation Board (NIB) research site. The land was cleared of all bushes, ploughed and harrowed to prepare the seeding bed. The area was then divided into 4 main plots of 39 m x 11 m size each with a 5 m uncultivated strip to separate the main plots. Each main plot was then sub-divided into 30 sub-plots measuring 3 m x 3 m with 1 m boundary, to allow 5 replications per species.

The experiment was a split-plot factorial design in a completely randomized design comprising of two factors, grass species and soil moisture content at 6 and 4 levels, respectively. Each main plot was randomly assigned a moisture level treatment scheduled as follow: T1 was 80% of the field capacity (FC), T2 was 50% of FC, T3 was 30% of FC and T was the control (rain fed). The second level treatment was grass species randomly assigned to the 30 sub-plots within each of the 4 main plots. The grass species treatments were; *Chloris roxburghiana* (CR), *Eragrostis superb* (ES), *Enteropogon macrostachyus* (EM), *Cenchrus ciliaris* (CC), *Chloris gayana* (CG), *Sorghum sudanense* (SB).

Experimental materials, Sowing and Irrigation

Gypsum blocks (GBs - electrical resistance blocks) were used to determine different soil moisture content levels and monitoring soil moisture changes. This were selected for ease of measuring soil moisture changes for effective recharge at desired levels of 80, 50 and 30% FC soil moisture content. The method was also used in determining soil moisture recharge times to maintain prescribed moisture contents. GBs were installed in the middle of each sub plot, at two depths, 15 and 30 cm in separate holes which were dug using a 50 mm soil auger. These depths were within the root zone of the grass species (45 cm). Prior to installation, GBs were soaked overnight as recommended (Orloff, 2003). Before installation, the GBs were calibrated to have readings corresponding 80%, 50%, and 30% FC soil moisture content by use of moisture meter. After installation, wire ends originating from the installed blocks for taking the readings were carefully supported by vertical sticks for ease of taking readings and identification of installation points.

The seeds were provided by Kenya Agricultural Research Institute (KARI), Kiboko Range Research Station. Before planting, the seeds were tested for germination percentage using the standard seed test by germination method as described by ISTA (1976) for the determination of sowing rate before sowing by broadcast method. Phosphate fertilizer was applied to the treatments with a rate of 200 kg ha^{-1} to enhance establishment. Thereafter, no fertilizer application was done for the whole data collection period. All other routine pasture husbandry practices such as weeding were done for all the treatments. Irrigation based on the GBs reading, ensured the predetermined soil moisture along treatments. The irrigation was done using overhead sprinkler irrigation.

Determination of water use efficiency

Water use efficiency was estimated by water productivity (WP) approach which is an efficiency term, expressing the amount of marketable product (kilograms of grain/ grass biomass etc) in relation to the amount of water in (mm) needed to produce that output. Soil water balance of the root zone was used to estimate the evapotranspiration (ET) in (mm). This was based on the changes in soil moisture content (ΔS) of crop root zone, which is equal to the difference between the amount of water added to the root zone (Qi) and that withdrawn from it (Qo) in a given time interval (Hillel, 1998; Kendy et al., 2003) as expressed in Equation (1).

$$\Delta S = Qi - Qo \qquad (1)$$

Equation (1) was used to determine (ET) of grass species as follows;

$$ET = P + I + U - R - D - \Delta S \qquad (2)$$

Where, ΔS = change in root zone soil moisture storage, P = Rainfall, I = Irrigation, U = capillary rise into the root zone, R = Runoff, D = Deep percolation beyond the root zone, and ET = Evapotranspiration (Evaporation + Transpiration). All quantities were expressed as volume of water per unit land area (length units).

In order to use Equation 2 to determine ET in this study, the parameters measured were amount of water added to the field by rain and irrigation. In the study area, the gradient was flattish (<5%) and runoff was negligible. The water table is deep (Maingi and Marsh, 2002) U was deemed negligible. There was no deep percolation in this study since irrigation never allowed to achieve the 100% FC. Therefore, Equation (2) was rewritten for the purpose of this study to give Equation 3;

$$ET = P + I - \Delta S \qquad (3)$$

The estimated WUE was computed as the dry matter yield (kg DM ha^{-1}) per unit of water evapotranspired by the grasses at phonological growth stages of 8, 10, 12, 14 and 16 weeks, following Equation (4) (Cooper et al., 1988; Karuku et al., 2014).

$$WUE\left(kg\,DM\ ha^{-1}\ mm^{-1}\right) = \frac{Yield\ \left(kg\ DM\ ha^{-1}\right)}{ET_{grass}\left(mm\right)} \qquad (4)$$

Where, WUE is water use efficiency, ETgrass is amount of evapotranspiration by each grasses species in (mm).

Rainfall data

Monthly rainfall data for Tana River County was provided by the Kenya National Drought Management Authority (KNDMA) from 2000 to 2013 to help in understanding the county's rainfall distribution pattern, and rainfall distribution over the 2012-2013 experimental periods. Daily rainfall data was also collected within the National Irrigation Board research site located 200m from the experimental site which was later used to calculate water supplied by rainfall to the grasses presented as (P) in Equations (2) and (3).

Data analysis

Data collected was subjected to Analysis of Variance (ANOVA) using SAS Version 9 to determine the significance of the treatment effects of the different soil moisture content on productivity and WUE of the different grass species. Where significant difference was detected, the means were separated by Least Significant Difference (LSD) at 5% probability level.

RESULTS

Climatic data

Figure 2 presents the average monthly rainfall trends (mm) for 2012/2013 and monthly long term mean from 2000-2013 for Tana River County. The rainfall pattern showed March-May 2012 had higher average rainfall than the same months in 2013. The three months were the expected long rain season in the County. Similar trend was also noted for short rain season of October-December, 2013 which had lower average monthly rainfall amounts than the same months in 2012. The long-term monthly average rainfall showed similar trends for the same long rain season of March-April being lower in 2013 compared to 2012.

Figure 3 presents the average monthly rainfall amounts (mm) and trends during the experiment period (September, 2012 to April, 2013). The cumulative rainfall amounts for the four months of September-December 2013 were 266.1 mm. This was the active growing period during biomass data collection and calculation AGDM yields used for WUE calculation.

Table 1 presents the amount of rainfall, irrigation water and the soil moisture changes that were used to derive the evapotranspiration (ET) at the different phenological stages that was used in the calculation of WUE. The

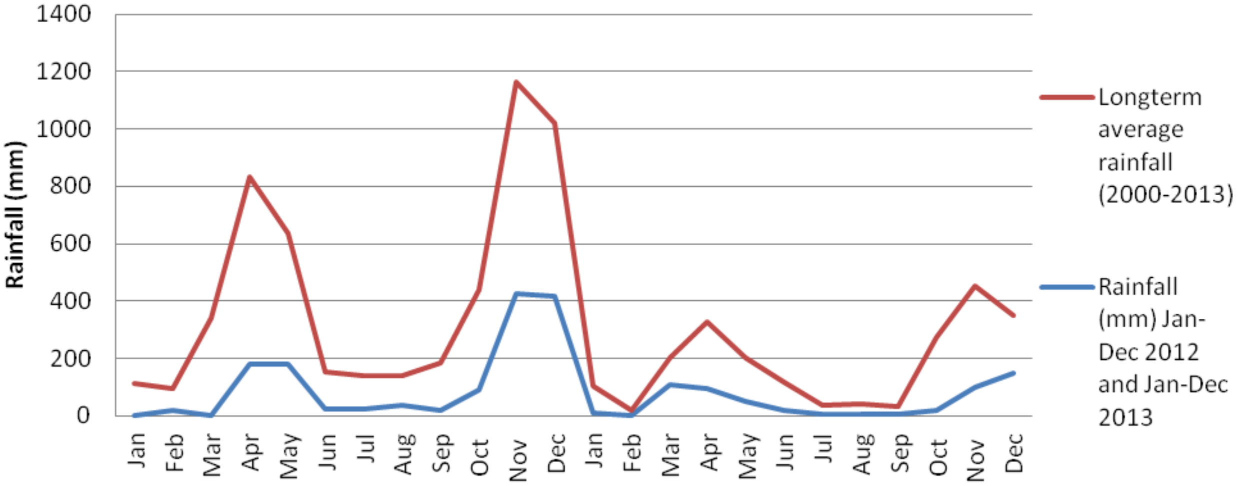

Figure 2. Tana River County monthly rainfall trends for 2012 and 2013 compared to long term average rainfall for 2000-2013.

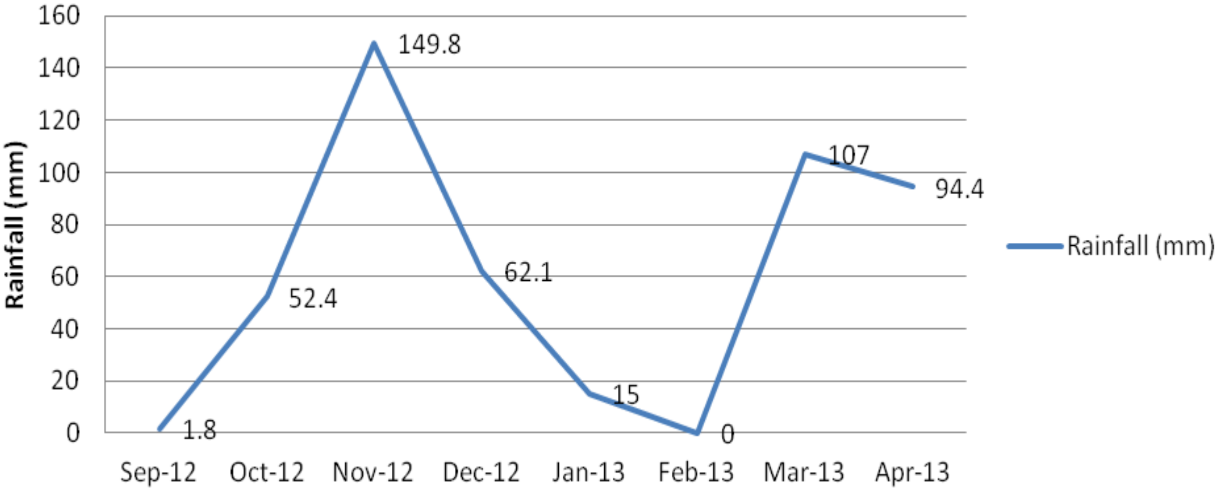

Figure 3. Eight months rainfall trends and amounts (mm) during experimental growing period and drought tolerance (Sep 2012 to Apr 2013).

table shows evapotranspiration increased with phenological growth stages among all the moisture level treatments.

Water use efficiency

Table 2 presents the biomass yields used to calculate the Water Use Efficiency (WUE) of the selected grasses at different phenological stages under varying soil moisture content. Rainfed treatment had significantly ($p<0.05$) lower WUE compared to the three soil moisture content. There was a declining trend in WUE with grass species at maturity where *S. sudanense* had higher WUE at 8, 10 and 12th weeks (> 15 kg DM ha^{-1} mm^{-1}) in all the treatments followed by *C. gayana* and *E. macrostachyus* and were significantly ($p<0.05$) different from *E. superba, C. ciliaris* and *C. roxburghiana* that had WUE less than10 kg DM ha^{-1} mm^{-1} among the six grass species. The 30% FC soil moisture content had significantly ($p<0.05$) higher WUE at all the phenological stages *for S. sudanense, C. gayana, C. ciliaris and E. macrostachyus* compared to 80, 50% FC and rainfed with all having WUE greater than 20 kg DM ha^{-1} mm^{-1}.

Table 1. Rainfall amount (mm), irrigation (mm), soil moisture change and evapotranspiration for the 80, 50 and 30% FC soil moisture content and rainfed.

Parameter	Values				
	Week 8	Week 10	Week 12	Week14	Week 16
80% field capacity					
Rainfall (P) in (mm)	54.2	224.2	204	242.5	281.1
Irrigation (I) in (mm)	367	484	556	664	770
Soil moisture change (ΔS)	147	210	214	198	144
Evapotranspiration (ET)	274.2	498.2	546	708.5	907.1
50% field capacity					
Rainfall (P) in (mm)	54.2	224.2	204	242.5	297.9
Irrigation (I) in (mm)	289	366	442	524	669
Soil moisture change (ΔS)	121	187	203	113	105
Evapotranspiration (ET)	222.2	403.2	443	653.5	861.9
30% field capacity					
Rainfall (P) in (mm)	54.2	224.2	204	242.5	297.9
Irrigation (I) in (mm)	211	280	310	215	456
Soil moisture change (ΔS)	98	268	225	230	265
Evapotranspiration (ET)	167.2	236.2	289	227.5	488.9
***Rainfed**					
Rainfall (P) in (mm)	54.2	224.2	204	242.5	297.9
Irrigation (I) in (mm)	0	0	0	0	0
Soil moisture change (ΔS)	33	79	85	67	113
Evapotranspiration (ET)	21.2	145.2	119	175.5	184.9

DISCUSSION

These results demonstrated the grasses have varied WUE that was influenced by water availability, stage of maturity and species. The higher WUE for *S. sudanense, C. gayana* and *E. macrostachyus*, is an indication that these species have potential for higher yields even at lower moisture levels and hence making them suitable for drylands. The lower WUE for all the six grass species under rainfed treatment compared to the irrigated treatments may be attributed to low available moisture in soils hence reduced yield. The water stress under rainfed pastures affected plant growth and development as a result of reduced evapotranspiration compared to the irrigated (Table 1). This was also reported by Munns (2002) under rainfed agriculture in arid environments. Guenni et al. (2002) evaluated response to droughts of five species of *Bracharia* and reported that water stress affected the root-shoot ratio for many tropical grasses and hence reduced WUE. This could explain why grass species under rainfed conditions in this study had lower yields per unit of rainfall water.

Photosynthesis and other plant physiological processes are affected by limited water supply which can also explain the low WUE under rainfed conditions. The understanding of WUE of range grasses is important for scheduling irrigation and making appropriate management decisions regarding the use of scarce water resource (Khan et al., 2008; Blum, 2005).

The evaluation of WUE is critical in making appropriate decisions for the management of plant water requirements under irrigation; this includes the choice of plant/crop depending on its efficiency in utilizing limited water available in water deficit environments. This study indicated *S. sudanense* and *C. gayana*to showed better WUE compared to the others species. Eneji et al. (2008) also reported *S. sudanense* is less susceptible by water deficit and has a high WUE due to higher root density and drought tolerance abilities of the species. A study by Snyman (1994) assessed WUE of *Anthephora pubescens, Cenchrus ciliaris, Chloris gayana, Digitaria eriantha, Eragrostis curvula* and *Panicum maximum* pasture species in the semi-arid rangelands of South Africa over a period of three years. He reported that *C. gayana* had higher productivity than the other six species in both wet and drier conditions with higher WUE (7.2 kg

Table 2. Biomass yields (kg ha^{-1}) and Water Use Efficiency (WUE) in (Kg DM ha^{-1} mm^{-1}) of six range grass species grown at 80, 50 and 30% FC soil moisture content and rainfed.

Parameter	**80% FC**		**50% FC**		**30% FC**		**Rainfed**	
Week 8	**Biomass**	**WUE**	**Biomass**	**WUE**	**Biomass**	**WUE**	**Biomass**	**WUE**
C R	2000.4^{a}	7.3^{a}	3264.2^{b}	14.7^{b}	1264.3^{a}	7.6^{a}	164.5^{a}	7.8^{a}
E S	1668.6^{a}	6.1^{a}	1164.3^{a}	5.2^{a}	1132.4^{a}	6.8^{a}	132.3^{a}	6.2^{a}
EM	3664.2^{b}	13.4^{b}	5400.5^{c}	24.3^{c}	4332.9^{b}	25.9^{c}	332.7^{a}	15.7^{a}
CC	2200.5^{a}	8.0^{a}	5064.1^{c}	22.8^{c}	4264.5^{b}	25.5^{c}	264.3^{a}	12.5^{b}
CG	8400.6^{d}	30.6^{c}	3932.1^{b}	17.7^{b}	6400.2^{d}	38.3^{d}	240.5^{a}	11.3^{b}
SB	7800.6^{d}	28.4^{c}	5200.3^{c}	23.4^{c}	5800.6^{c}	34.7^{d}	410.7^{a}	19.4^{b}
Week 10								
C R	3120.4^{b}	6.3^{a}	1544.4^{a}	3.8^{a}	2264.1^{a}	9.6^{a}	264.4^{a}	1.8^{a}
E S	1532.1^{a}	3.1^{a}	932.2^{a}	2.3^{a}	1732.5^{a}	7.3^{a}	332.6^{a}	2.3^{a}
EM	3532.3^{b}	7.1^{a}	5464.1^{c}	13.6^{b}	4732.1^{b}	20.0^{c}	432.5^{a}	3.0^{a}
CC	2532.5^{a}	5.1^{a}	3732.2^{a}	9.3^{a}	5664.1^{c}	24.0^{c}	464.8^{a}	3.2^{a}
CG	4532.2^{c}	9.1^{a}	7732.5^{d}	19.2^{b}	6600.5^{d}	27.9^{d}	305.1^{a}	2.1^{a}
SB	10064.5^{e}	20.2^{c}	7732.6^{d}	19.2^{b}	7400.6^{d}	31.3^{d}	540.4^{a}	3.7^{a}
Week 12								
C R	3600.4^{b}	6.6^{a}	2532.3^{a}	5.7^{a}	2732.3^{a}	9.5^{a}	732.5^{ab}	3.2^{a}
E S	3468.3^{b}	6.4^{a}	1800.5^{a}	4.1^{a}	3264.1^{b}	11.3^{b}	364.1^{a}	3.1^{a}
EM	6600.6^{d}	12.1^{b}	7400.7^{d}	16.7^{b}	5400.1^{c}	18.7^{b}	500.3^{a}	4.2^{a}
CC	4064.6^{b}	7.4^{a}	6532.9^{d}	14.7^{b}	5932.4^{c}	20.5^{c}	532.5^{a}	4.5^{a}
CG	7932.2^{d}	14.5^{b}	9400.6^{e}	21.2^{c}	9000.7^{e}	31.1^{d}	707.5^{a}	5.9^{a}
SB	9464.4^{e}	17.3^{b}	9200.5^{e}	20.8^{c}	7264.8^{d}	25.1^{d}	764.6^{a}	6.4^{a}
Week 14								
C R	2400.2^{a}	3.4^{a}	1800.5^{a}	2.8^{a}	3264.5^{b}	14.3^{b}	764.2^{a}	4.4^{a}
E S	4332.5^{b}	6.1^{a}	1200.6^{a}	1.8^{a}	3600.7^{b}	15.8^{b}	381.0^{a}	2.2^{a}
EM	5132.9^{c}	7.2^{a}	9000.8^{d}	13.8^{b}	6400.9^{d}	28.1^{d}	604.3^{a}	4.4^{a}
CC	2532.4^{a}	3.6^{a}	8400.2^{d}	12.9^{b}	5332.1^{c}	23.4^{c}	558.2^{a}	3.2^{a}
CG	9000.3^{e}	12.7^{b}	9532.1^{e}	14.6^{b}	9400.5^{e}	31.3^{d}	767.0^{a}	4.4^{a}
SB	12664.7^{e}	17.9^{b}	6864.2^{d}	10.5^{b}	7124.3^{d}	31.3^{d}	824.9^{ab}	4.7^{a}
Week 16								
C R	3320.6^{b}	3.6^{a}	2532.3^{a}	2.9^{a}	2132.6^{a}	4.4^{a}	759.8^{ab}	3.1^{a}
E S	5600.3^{c}	6.1^{a}	1532.2^{a}	1.8^{a}	3132.7^{a}	6.4^{a}	372.3^{a}	2.0^{a}
EM	6464.5^{c}	7.0^{a}	10464.4^{e}	12.1^{a}	6664.8^{d}	13.6^{b}	664.8^{a}	3.6^{a}
CC	2464.8^{a}	2.7^{a}	9132.6^{e}	10.6^{b}	6864.8^{d}	14.0^{b}	664.5^{a}	3.6^{a}
CG	10864.1^{e}	11.8^{b}	10200.1^{e}	11.8^{b}	10132.1^{e}	20.7^{c}	832.7^{ab}	4.5^{a}
SB	13664.2^{f}	14.8^{b}	11600^{e}	13.5^{b}	7664.5^{d}	15.7^{b}	964.8^{ab}	5.2^{a}

Means within the same columns with different superscripts are significantly different at ($p<0.05$). CR=*Chloris roxburghiana*; ES= *Eragrostis superb*; EM= *Enteropogon macrostachyus*; CC= *Cenchrus ciliaris*; CG= *Chloris gayana*; SB= *Sorghum sudanense.*

DM ha^{-1} mm^{-1}) than the other grass species. Our WUE values resulted to higher than those reported by Snyman (1994), probably due to the different climatic conditions and soil types within the two study areas. The highest WUE for *S. sudanense* and *E. macrostachyus* at the lowest irrigation level is related to their fast germination as an adaptive strategy, deeper and extensive rooting systems and hence the ability to fully exploit the supplied water coupled with high amount of biomass (Craine et al., 2013; Koech et al. 2014). This is consistently whit our finding, in which *S. sudanense* and *C. gayana* had higher germination rates. Evolution and adaptation mechanisms to water use efficiency could be the result of the observed variations among the six grasses at different soil moisture. The deeper rooted species like *S. sudanennse* had higher WUE exploiting deeper soil profiles and water availability at lower moisture level. This might have also played a role in this study where *S. sudanense* and *C. gayana* having deeper roots made the plants better suitable to water stress (Koech et al., 2014). However, this result represents only one growing season for the species and with the need for longer monitoring to assess if subsequent growing seasons (re-growth) may lead to a different growing response.

Conclusion

This study provided information on WUE of six grass species under varying soil moisture content. The results show that grass species have different capacities to utilize water. The findings demonstrate that range grasses have potential for high productivity under low moisture supply. *S. sudanense, C. gayana* and *E. macrostachyus* had high WUE at 30% FC soil moisture content compared to 80 and 50% FC soil moisture content, therefore are the suitable species under low soil moisture conditions. Other factors that may be affecting WUE such as species ecotypes require evaluation. There is also need for long term monitoring of WUE for the same species, to capture at least three growing seasons.

Conflict of interest

The author(s) did not declare any conflict of interest.

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