Effect of watering Frequency on Seed Germination and Seedling Performance of Four Range Grasses

W. Ngoyawu Mnene[1*], B.P. Ogillo[1], W.N. Ekaya[2] and J.I. Kinyamario[3]

[1]*Kenya Agricultural Research Institute, Research Centre - Kiboko, P.O. Box 12-901388 MAKINDU.*
[2]*University of Nairobi, College of Agriculture and Veterinary Sciences, Department of Land Resource Management and Agricultural Technology, Nairobi, Kenya.*
Email: ekaya@africaonline.co.ke
[3]*University of Nairobi, School of Biological Sciences, Department of Botany, Nairobi, Kenya.*
Email: jenesiok@uonbi.ac.ke
[*] *Corresponding author, email: william_mnene@yahoo.co.uk*

Abstract

Degraded rangelands resulting from continuous overgrazing, frequent drought, termites, uncontrolled burning, opportunistic cultivation and other anthropogenic factors could be rehabilitated through reseeding. However, in semi-arid areas where reseeding ought to be more successful, such attempts have failed even when the rains are normal. An on-station study was carried out with rangeland grasses potted in a common soil, orthic Ferralsol, subjected to same amount of watering provided in four regimes over 70 days. The grasses were *Cenchrus ciliaris* (L), *Chloris roxburghiana (*Shult.), *Enteropogon macrostachyus* (A. Rich) and *Eragrostis superba (*Peyr.*)*. Watering frequency affected soil moisture, seedling counts and seedling growth performance of all four species. Generally, grasses performed best under every third day watering. This not only demonstrated that soil moisture content is an important factor influencing seed germination and subsequent plant development of all the four grasses but also that rainfall storm frequency characteristics would influence reseeding success even when the seasonal total is normal.

Paper to be presented at the 11th KARI Biennial Scientific Conference on 10-14 November, 2008

INTRODUCTION

Rainfall in arid and semi-arid rangelands is described as erratic in terms of unreliable amounts and distribution patterns. This poses a major challenge to reseeding programmes (Herlocker 1999; Dolan *et al*., 2004). While some grass species are drought tolerant, others wither quickly under moisture stress. Soil moisture fluctuates in resonance to recharge from rainfall and as such where rain storms occur with a long delay period, young plants are liable to stunted growth or outright death. Therefore, even with a normal total amount of rainfall, the distribution of the season's storm events is likely to affect reseeding efforts. This study was conducted to investigate the effect of watering frequency on grass seed germination and seedling development. The purpose is to demonstrate that reseeding failure could occur depending on rainy season's behaviour even where the total amount is normal.

MATERIALS AND METHODS

Study area description

Location

The research study involved experiments on-station work carried out at Kenya Agricultural Research Institute (KARI) Kiboko Research Centre. The Kiboko Research Centre is situated about 2.3^{o}S and 37.8^{o}E, 1000 m above sea level and under eco-climatic zone V (Michieka and van der Pouw 1977). Kiboko receives 600 mm annual rainfall characterized by bimodal distribution with peaks in April and November, 30^{o}C mean maxima and 20 ^{o}C mean minima temperatures, plain landscapes with mostly sandy and sandy loam soils derived from Basement rocks or colluvial in origin, thorn-bushland and thickets dominated by *Commiphora* and *Acacia* trees and perennial grasses dominated by *Chloris roxburghiana* and *Cenchrus ciliaris*.

Soil type selection and preparation

The Kiboko research Centre soils were classified by and mapped by Michieka and van der Pouw (1977). The predominant soils are orthic Ferralsol, rhodic Ferralsol and histic Gleysol. Based on a study to investigate which of them would best support establishment of an assortment of grasses mostly used for reseeding, orthic FERRASOL ranked highest. Therefore, this soil was selected for this study. The top 0-15 cm soil was collected from the field and cleaned of large sized debris, stones, roots and litter so as not to damage the pots during soil compaction.

Seed preparation and sowing

Seeds of *C. ciliaris*, *C. roxburghiana*, *Enteropogon macrostachyus* and *Eragrostis superba* were obtained from stock harvested previously from natural stands at KARI - Kiboko Research Centre. Pure germinating seed (PGS) expressed as a percentage of total seed was determined at planting according to the laboratory procedures as described in HSU (1994). Whole seeds as dispersal units were sown by spreading on the surface soil in pots without covering.

Watering of experimental pots

Watering of the pots was done immediately after sowing using shower-rose fitted watering buckets with fine holes to provide a fine spray. The buckets were filled with pre-measured volumes for the respective treatments. Delivery height was maintained at 15 cm to minimize undue disturbance of the seeds and young seedlings. Watering was done between 0700 and 0900 h when it was cool in order to reduce evaporative losses.

Tap water, drawn fresh as and when required, was used to irrigate the pots. Its source was a natural spring near the study site. In the course of the experiment, water samples were submitted four times to KARI – NARL for analysis of pH and mineral content. Four watering regimes each lasting 70 days were applied: (1) Daily with 250 ml (2) Every other day with 500 ml (3) Every third day with 750 ml (iv) Every fourth day with 1, 000 ml. Henceforth the watering regimes will also be referred to as WR1, WR2, WR3 and WR4, respectively. The watering regimes were a simulation of seasons that usually last 70 days with rainstorms that may be heavy but far apart or light but frequent (Pratt and Gwynne 1977; Musembi 1986; Herlocker 1999). For each species, a gypsum block (Eijkelkamp Agrisearch Equipment, Netherlands) was randomly placed in four pots as per the manufacturer’s and other practitioners’ recommendations.

Experimental Design

The pots were laid out in 4 x 4 factor blocks replicated 3 times. Each of the four species was assigned four pots at random for each of the four watering regimes in each of the three replications. The four watering regimes formed the main plots each with 48 pots. The total number of pots was 192 with additional 48 pots, included as checks for potential presence of natural soil seed bank. The seedling count observed in the check pots provided a correction factor for those in the seeded pots through discounting.

Data Collection and analysis

The experiment was conducted between July and October 2001. Data were collected on soil moisture, seedling count and their morphometric characteristics (height, tillers, leaf senescence and biomass). Analysis involved a comparison of the measured and calculated parameters of the species by watering regime using the General Linear Models (GLM) procedures. The Statistical Analysis Systems (SAS, 1990) software was used for the statistical analysis of the data. Duncan's Multiple Range Test was used ($p<0.05$) to test statistical significance of differences between means.

RESULTS AND DISCUSSION

Water analysis

Apart from the sulphates, all water components remained the same throughout the study period. According to the laboratory report the carbonate, chloride and sulphate levels were considered too high and unsuitable for horticulture purposes. However, according to standards elsewhere, irrigation water should not have an electrical conductivity (EC) that exceeds 3, 000 mmhos/cm or a sodium adsorption ratio (SAR) greater than 10. In which case therefore, the tap water at Kiboko with an EC of 1,600-1,650 mmhos/cm and SAR of <0.5 was considered safe for this grass trial experiment.

Soil moisture

Mean daily soil moisture index was 47.24 ± 0.88 % with a range of 0 – 98. However, soil moisture content fluctuated significantly ($p < 0.001$) from day to day 70. The mean soil moisture of 47.2% attained in this study was similar to that observed by

Keya (1997) in a study in northern Kenya. Generally, the plant's physiological processes and external factors such as temperature, humidity and air movement control transpiration (Larcher, 1983). As plants use water for growth, soil moisture is depleted.

Seedling population

Mean seedling population per pot was 15.66±1.263. Seedling populations varied significantly ($p < 0.001$) between grass species. Of these, majority were *E. macrostachyus* which were approximately twice as many as *C. ciliaris*, the next most abundant and over four times those of *C. roxburghiana*, the least abundant.

Seedling counts varied significantly ($p<0.05$) among watering regimes. The highest seedling count was observed under the every third day watering and the lowest, 8.02 ± 1.243 under daily regimes for all species. The second was every fourth day watering regime except *C. roxburghiana* for which every other day watering ranked second. Attainment of rapid ground cover is desirable range rehabilitation so as to reduce soil moisture loss through evaporation. More importantly, more seedlings imply a greater potential for faster range improvement which apparently could be achieved with *E. macrostachyus* under every four days watering regime.

Table 1: Mean (±SE) species seedling counts of four grass species within watering

Species	Watering regime			
	Daily	Every 2 days	Every 3 days	Every 4 days
Cenchrus ciliaris	7.92±1.811[a*]	11.83±2.386[ab]	26.50±6.045[c]	16.50±2.463[b]
Chloris roxburghiana	3.67±0.772[a]	8.75±2.038[cb]	11.50±2.536[c]	6.58±1.743[b]
Enteropogon macrostachyus	16.75±3.398[a]	23.42±3.573[a]	47.42±9.711[b]	37.50±6.158[b]
Eragrostis superba	3.75±1.243[a]	7.75±1.741[b]	10.33±1.990[c]	10.42±2.109[c]

[*] Means within a row with same superscripts indicate that they are not significantly different ($P<0.05$).

Seedling vegetational characteristics

Tillering formation

The first tiller was observed 28 days post sowing. The tillering rate differed significantly ($p < 0.001$) between the four grass species. The first species to tiller was *C. ciliaris* that was growing in the orthic Ferralsol under every other day watering regime. Watering frequency significantly ($p < 0.001$) affected plant tillering pattern. Initially, the difference in tillering between watering regimes was minimal but it increased such that by day 36 significant ($p < 0.001$) differences emerged.

Tillers are formed from auxiliary buds of ontogenetically older parental phytomers at the nodes where leaves emerged (Manske, 1998). They appear by the time the grass seedling has 4-5 leaves and the rate increases up to 4-8 weeks after sowing depending on crowding and environmental limitations (Skerman and Riveros, 1990). In this study therefore, the tillering process was within the range of time period referred to. Tillering of a plant is advantageous because it increases flowering points and subsequent seed production and increases canopy cover thereby protecting the ground thus reducing soil moisture loss through evaporation. Tillers also increase the amount of foliage and hence provide more feed to animals and increase a plant's chances of survival after its apical meristem is 'accidentally' lost through herbivory or fire before maturity (Skerman and Riveros, 1990). Thus, tillering is a good sign of perenniality / persistence, lack of which was a problem cited by the farmers about some of the species they had tried to establish unsuccessfully.

Leaf senescence

Senescence varied significantly ($p<0.01$) between species and watering regime. *Cenchrus ciliaris* contributed significantly ($p<0.001$) more dead leaves than the other three, the least being *C. roxburghiana*. This trend was consistently so regardless of watering regime (Fig. 1). Two grasses, *E. macrostachyus* and *E. superba* produced the same number of dead leaves except under every four day watering where the latter produced a significantly ($p<0.05$) higher number. The grasses were observed to stay green longer under low quantity but high frequency of watering. When leaves turn brown, they lose photosynthetic capacity due to reduced chlorophyll. As such, the greater the proportion of dry leaves there is on a plant the less chance it has of attaining its growth and production potential (Hacker and Ratcliff, 1989).

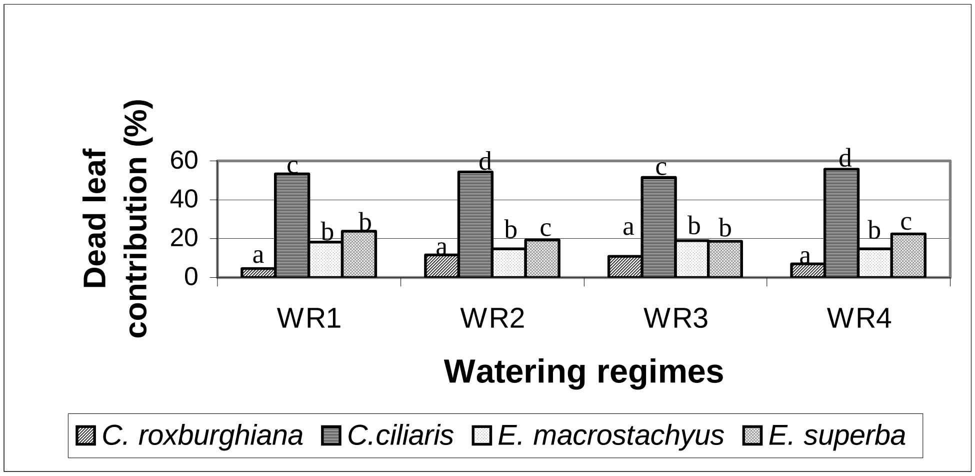

Figure 1: Relative contributions (%) to total number of dead leaves by four potted grasses

Above ground standing crop estimation and partitioning

The mean dry weight was 14.50 $\pm$ 0.778 g per pot, equivalent to 204.23 $\pm$ 10.958 g m^{-2} with a mean dry matter (%DM) of 41.47 $\pm$ 1.659. Most of the standing crop was in the leaf component (63.94 $\pm$ 1.950%), while stems comprised 22.49 $\pm$ 1.693% and panicles 13.57 $\pm$ 1.035%. Of these components, watering regime significantly ($p<0.05$) affected total dry matter, %leaf and %stem but did not significantly ($p>0.05$) affect %DM. *Cenchrus ciliaris* had significantly ($p<0.001$) more dead leaves than the other three, the least being *C. roxburghiana*. This trend was consistently so regardless of watering regime. Two grasses, *E. macrostachyus* and *E. superba* produced the same number of dead leaves except under every four day watering where the latter produced a significantly ($p<0.05$) higher number. Biomass production is to a farmer the means to the ultimate objective, increasing livestock productivity. Therefore, growing conditions that favour high seed germination and seedling establishment are most appropriate.

Conclusion

Watering regime affected soil moisture in this study. Subsequently, soils moisture content was an important factor influencing seed germination and subsequent plant development of all the four grasses. By implication, rainfall storm frequency characteristics would influence reseeding success even when the seasonal total is normal. However, further research is necessary so as address more species and more types of soil. This could also include multi-site transplanting.

Acknowledgement

The authors wish to thank KARI Kiboko staff who assisted in the implementation of this study, particularly Mr. James Ndemwa Ituli, Mr. Peter Mweki and Mr. Simon Mwangi Mwaura for actual data collection. We also thank the Director KARI, Dr. Romano Kiome for providing an enabling environment and Dr. Helga Recke, the Programme Coordinator, Agriculture / Livestock Research Support Programme Phase Two (ARSP II). Finally, we thank all the anonymous reviewers who helped to develop this paper. Funding was provided by the European Union. This study was part of a PhD Thesis for the first author; entitled 'Strategies to increase success rates in natural pasture improvement through re-seeding degraded semi-arid rangelands of Kenya' submitted to and successfully defended at the University of Nairobi in 2006.

References

Dolan D, Defoer T, Paultor G and Lundgren B. 2004. Kenya Arid and Semi-Arid Lands Research Programme. Final Feasibility Report. Kenya Agricultural Research Institute, Nairobi, Kenya.

Hacker, J.B. and D. Ratcliff, D. 1989. Seed dormancy and factors controlling breakdown in buffelgrass accessions from contrasting provenances. *J. Appl. Ecol.*, 26: 201-212.

Herlocker, D. 1999. Rangeland resources in eastern Africa: their ecology and development. German Technical Cooperation, Nairobi (Kenya). Nairobi (Kenya): GTZ. 213p.

HSU (Herbage Seed Unit). 1994. Forage Seed Production. ILCA Training Manual. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. 70pp.

Humphreys, L.R. and F. Riveros. 1986. Tropical pasture seed production. 3rd Edition. FAO Plant Productionand Protection. Paper 8. FAO (Food and Agriculture Organization of the united Nations), Rome, Italy.

Keya G.A 1997. Environmental triggers of germination and phenological events on an arid savanna region of northern Kenya. *Journal of arid Environments*, 37:91-106.

Larcher, 1983. Physiological Plant Ecology. Springer-Verlag, Berlin.

Manske, L.L. 1998. General description of grass growth development. Dickinson Research Centre, North Dakota State University, ND, USA. http://www.ag.ndsu.edu./dickinso/research/1998/range98a.htm.

Michieka,D.O. and van der Pouw. 1977. Soils and vegetation of Kiboko Range Research Station. Report 53, Kenya Soil Survey, Ministry of Agriculture, Nairobi.

Musembi, D.K. 1986. The seasonal climate of rangelands. In: Hansen, R.M., B.M. Woie and R.D. Child (eds.). Range research and development in Kenya. Winrock Intl. Inst., Morrilton, Arkansas, USA.

Pratt DJ and Gwynne MD 1977. Range Management and Ecology in East Africa. Hodder & Stroughton, London.

SAS Institute. 1990. SAS/STAT users guide. Version 6.1. Statistical Analysis Systems Institute (ed.), Cary, North Carolina, USA.

Skerman, P.J. and F. Riveros. 1990. Tropical Grasses. Food and Agriculture Organization of the United Nations, Rome. 832p.