

Effects of nitrogen and phosphorus on shoots and roots biomass of *Brachiaria* grasses in low fertility soils of North western Kenya

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Abstract

One of the major constraints to forage production in north western highlands of Kenya, is low soil fertility. The objective of this study was to assess the influence of nitrogen (N) and phosphorus (P) on growth and biomass production of *Brachiaria* grasses. Seven *Brachiaria* cultivars: *Brachiaria brizantha* cvs. Marandu, MG4, Piata, Xaraes, *B. decumbens* cv. Basilisk, *B. hybrid* cv. Mulato II and *B. humidicola* cv. Llanero were compared with two commonly grown forages, Rhodes grass and Napier grass cv. Kakamega 1. The treatments were tested in a split plot arrangement in a randomized complete block design with two rates of NP fertilizer, 0 and 40 kg P ha⁻¹ applied at planting and 50 kg N ha⁻¹ as a seasonal top-dress assigned to the main plot and the grass varieties as subplots. Shoots biomass was determined 14 weeks after seedlings emergence (WAE) and subsequent sampling done after every eight weeks. Roots biomass was assessed from 0-15 and 15 - 30 cm depths at 22, 46 and 80 WAE. During the wet season, the shoots biomass was significantly influenced by NP fertilizer ($p = 0.05$) and cultivars ($p=0.001$), but no significant interaction effects occurred. Fertilized grasses yielded 17% more shoots biomass than the unfertilized grasses. Basilisk, Marandu and Xaraes had the highest biomass yields (8.6 – 11.3 t ha⁻¹) and were higher ($p = 0.05$) than Rhodes grass, and also the other *Brachiaria* cultivars. Roots biomass was higher at the 0 - 15 cm depth at all sampling times and decreased with depth. *Brachiaria* cultivars had high roots biomass than Napier and Rhodes grass. Fertilizer response to roots biomass was only noted at 22 WAE only. Basilisk and MG4 are the best *Brachiaria* options for the north western highlands due to their higher shoots and roots biomass yields.

Key words: Dry and wet season, fertilizer, soil quality, shoots biomass.

Introduction

Livestock production is one of the most important agricultural land use systems in the world, with grasslands covering 25% of land surface and contributing to the livelihoods of more than 800 million people (Steinfeld *et al.*, 2006). However, the Kenyan dairy industry is threatened by seasonal forage production of low nutritional quality. Excess forage production is experienced during the rainy season but more often, acute shortages occur in the dry season (Njarui *et al.*, 2016). The abundant natural forages relied upon by farmers is not sufficient to satisfy animal requirements especially in the dry season when biomass production decreases by 25 - 50% and crude protein levels reduce significantly (Penning de Vries and Djiteye, 1982). Soil nutrient depletion and improper management of improved forages exacerbates the problem leading to soil degradation and reduced livestock production.

Forage grass production is influenced by the varietal potential including growth and development processes within the grass and soil nutrient availability. Grasses have a relatively high demand for nutrients. McKenzie (2005) for example reported that most hay grasses in

Alberta removed an average of 14-18 kg nitrogen (N) and 1.8 kg of phosphorus (P) per ton of dry matter. However, the amounts of nutrients removal vary depending on the grass species and the seasonal conditions. High nutrient uptake and removal occur in the wet seasons due to increased nutrient availability in soil solution. Productivity of forages is limited by low soil fertility especially in the low pH and N and P deficient soils that are common in the north western highlands of Kenya. Nitrogen is an important element in grass production due to its role in photosynthesis and influence in the chlorophyll molecule (Oliveira *et al.* 2010). Where available N from soil is not sufficient for forage production, application of fertilizer N may provide immediate responses in forage grasses (Batista *et al.*, 2014). Silveira *et al.* (2015) working with different N rates (0, 60 and 120 kg ha⁻¹ per year) on *Paspalum notatum* for a period of three years, observed that the dry matter yields increased linearly with application rates of N. However, responses to P have only been reported in the season of application during grass establishment due to the role of P in roots formation but not in later seasons. Higher nutrient removal is reported in improved grasses than indigenous grass species though some grasses have also been bred for low soil fertility regions (Rao *et al.*, 1993).

Brachiaria grasses though indigenous to East Africa, have been recently introduced in Kenya. The introduction of these grasses into the smallholder farming systems of north western highlands, necessitates, proper soil fertility management and an understanding of its nutritional requirements for pasture management. Studies on the fertilizer needs of Brachiaria grasses in the low fertility soils in the region is therefore necessary in order to increase the production of feeds for higher milk and meat production per unit of area. In the previous studies, Miles and Lapointe, (1992) reported good performance of *B. humidicola* in infertile soils of Carimagua, while *B. ruziensis* performed better in relatively fertile clay loam soils due to its high N demand (Humphreys *et al.*, 1988). The objective the study was to assess the effects of N and P fertilizers on the shoots and roots biomass of seven Brachiaria cultivars in north western highlands of Kenya. We hypothesized that the shoots and roots biomass of Brachiaria grasses is increased by N and P fertilization in nutrient depleted soils, and the response is also dependent on the season.

Materials and methods

Study sites

The experiment were conducted in the Kenya Agricultural and Livestock Research Organization (KALRO) Kitale and at the University of Eldoret farms, located in Trans Nzoia and Uasin Gishu Counties respectively within the north western highlands of Kenya. The KALRO Kitale site (1° 0' 6.6''N and 34° 59' 10''E) lies within the Upper Midlands (UM) 4 agro-ecological zone at 1890 m asl. The site has a cool and temperate climate with average annual temperatures ranging between 10 and 27°C and a mean annual precipitation of 1100 mm, making it reliable for rain fed agriculture. The rainfall is unimodal and starts from April to December. The soils are mainly humic Acrisols (FAO, 2008; Jones *et al.*, 2013), which have low fertility, are deficient in N and P, have a weak to moderate sub-angular blocky structure and low organic matter. They are well drained with high moisture storage capacity.

The University of Eldoret site lies between 1°0'6.6''N and 34°59'10''E at an elevation of 2073 m asl in the Lower Highland (LH) 3 agro-ecological zone which covers 58% of the county. Eldoret receives a unimodal rainfall between April and November with averages of 900 mm. Since the area has no distinct dry and wet seasons, the dry season in this study was considered as the periods with lower rainfall amounts (October to April). Temperature ranges between 7 and 29°C, making the area favorable for fodder and livestock production. The soils are underlain by murrum, well drained, shallow to moderately deep and with dark red friable clay of petroplinthite. They are classified as Rhodic Ferralsols and are low in soil pH (<5.5), N and P contents, moisture storage capacity and prone to Al toxicity (Kisinyo, 2011; NAAIAP and KARI, 2014).

Site characterization

Soil samples were collected prior to commencement of the trials using a soil auger. Samples were taken using a W- pattern from four depths: 0 – 15 cm, 15 – 30 cm, 30 – 60 cm, and 60 - 100 cm thoroughly mixed and a sub sample was taken from each depth for each block. After air drying, the samples were gently crushed to pass through a 2-mm sieve. Available P (Mehlick III), exchangeable K, Ca, Mg and total N were estimated after wet digestion with H₂O₂/H₂SO₄ as described by Okalebo *et al.* (2002). Total Ca²⁺, Mg²⁺, and K⁺ were determined by atomic absorption spectrometry and P measured as described by Murphy and Riley (1962). Soil pH was measured in water (soil: water ratio of 1: 2.5) using a pH meter with a glass and reference calomel electrode (Model pH 330 SET-1, 82362). Soils were vertically sampled using stainless steel rings (diameter 10 cm) for different depths; resulting in undisturbed soil samples for bulk density determination as described by Blake and Hartge (1986). The samples were dried at 65°C to a constant weight to allow soil bulk density determination. All determinations were made in triplicate and expressed on a dry weight basis.

Soil chemical characteristics

The soils were deeper in Kitale (>100 cm) than Eldoret (up to 50cm). Soil depth is an indicator of volume of water storage and extent of root growth expected in the soil especially for deep rooted forage grasses (Bengough *et al.* 2016). Low soil depth coupled with low water storage capacity of Ferralsols (Jones *et al.*, 2013) could hinder growth of grasses with extensive deep roots systems in Eldoret. The bulk density ranged from 1.34 to 1.49 g cm⁻³ and between 1.29 to 1.35 g cm⁻³ in Kitale and Eldoret, respectively. The bulk density were within the normal range (<1.5 g/cm³) that doesn't restrict root growth in soil as proposed by Hunt and Gilkes (1992). Soils were generally medium acidic in both sites, but slightly more acidic in the 30 - 60 cm depth in Kitale (Table 1). The soils were mainly deficient in N, available P and Zn with nutrient levels decreasing with depth in both sites. The soil are generally low in organic C ranging from 0.2 - 0.3% in both sites. However, K, Ca, Mg and Mn were adequate in both sites.

Table 1 Initial soil physical and chemical properties at the experimental sites, Kitale and Eldoret

Parameters	Kitale			Eldoret	
	0 - 30 cm	30 - 60cm	60 - 100cm	0 - 30cm	30 - 50cm
Soil pH	5.76	5.50	5.66	5.86	5.77
Bulk density (g/cm ³)	1.49	1.46	1.34	1.29	1.35
Total N (%)	0.03	0.02	0.02	0.03	0.02
Organic C (%)	0.3	0.2	0.2	0.3	0.2
Available P (ppm)	18	6	5	15	10
Potassium (me %)	1.17	0.74	0.51	2.01	1.56
Calcium (me %)	4.5	4.3	2.2	6.6	5.5
Magnesium (me %)	1.2	1.04	1.2	1.22	1.74
Manganese (me %)	0.29	0.16	0.20	0.38	0.36
Zinc (ppm)	1.79	1.56	1.03	4.92	2.41

Experimental design and management

The treatments consisted of seven *Brachiaria* grass cultivars *Brachiaria decumbens* cv. Basilisk, *B. brizantha* cvs. Marandu, MG4, Piata, Xaraes, *B. hybrid* cv. Mulato II and *B. humidicola* cv. Llanero and two commonly grown grasses (Rhodes grass cv. KAT R3 and Napier grass cv. KK1). The design was a randomized complete block in a split plot arrangements with or without fertilizer (40 kg P ha⁻¹ and 50 kg N ha⁻¹) being the main plot and the grasses as subplots and replicated four times. Phosphorus was applied at planting as triple super phosphate (TSP 46% P₂O₅) while N was top dressed with calcium ammonium nitrate (CAN 26% N) each season. The bare plots were kept weed free throughout the experimental period. These treatments were tested in subplots of 4 m by 4 m.

The seeds were drilled in a well prepared land at 5 kg ha⁻¹ for *Brachiaria* and 10 kg ha⁻¹ for Rhodes grass in 2 cm deep furrows and an inter-row spacing of 0.5 m. Root splits of Napier grass were planted at 1 m x 0.5 m spacing. Minimum tillage was practiced throughout the growth period to encourage maximum root growth. After full establishment phase (14 weeks after seedling emergence- WAE) a standardization cut was made to stimulate uniform plant growth. Subsequent harvests were carried out after every 8 weeks. During the harvest, the grass was cut at 5 cm above the ground within inner 4 m² using sickles. The fresh herbage was weighed, and a subsample taken, and then dried at 60°C to constant weight for determination of shoots biomass. The number of tillers from four (4) randomly selected plants within a 1 m x 1 m fixed quadrat frame was counted. Plot cover was determined by counting the number of fully covered subdivisions in a 1 m² quadrat (with 25 squares of 0.2 m x 0.2 m each) as described by (Njarui and Wandera, 2004) while in Napier grass, the plot cover was determined according method described by Sarrantonio (1991). Plant height and spread were measured in four (4) randomly chosen plants within a 1 m² quadrat. Spread was considered as the width of the widest point while height was taken from the base to the highest flag tip excluding inflorescence.

At harvest (22 WAE), subsamples were taken for determination of shoots biomass and nutritive value. After oven drying (60 °C for 48 hours) and milling, samples were analyzed for digestibility according to the procedure of Goering and Van Soest (1970). Crude protein was determined using micro-Kjeldahl according to the method of the Association of Official Analytical Chemist (AOAC, 2000).

Roots biomass assessment

Roots biomass assessment was conducted at 22, 46 and 80 WAE, representing one complete season in the area. The roots were sampled using the soil-core method (Bohm, 1979). Four soil cores were randomly sampled using a stainless steel auger at 0 - 15 cm and 15 - 30cm depths from the intra- and inter-row spacing in each plot. To prevent edge effects, the samples were taken at least 1 m from the edges. The samples from each depth were thoroughly mixed, weighed to determine the total bulk soil weight and a sub sample was collected for moisture correction. The roots contained in the samples were recovered under a tap of running water at low pressure using 2.8 cm and 2 cm mesh sieves (Bohm, 1979). Samples were dried in an air-forced oven at 65° C to constant weight and then weighed for determination of dry root weight. The roots biomass was calculated as a factor of the bulk density for each depth.

Statistical analysis

Analysis of variance was undertaken to determine the effects of fertilizer N and P on the shoots and roots biomass of *Brachiaria* grasses using Statistix 10 package (Statistix, 2003). Means were separated using the Tukey's HD test. Where ANOVA was significant ($P \leq 0.05$), Pearson correlation was performed to assess relationships between the shoots and roots biomass and growth parameters including tiller numbers, plant height, spread and cover.

Results and Discussion

Shoots biomass

During the dry season (October – April), a significant site ($P < 0.001$) and cultivar effect ($P < 0.001$) was noted. The grasses produced higher yields in Kitale (8.9 t ha⁻¹) than in Eldoret (4.2 t ha⁻¹) mainly due to differences in moisture. The soils in Kitale are mainly Acrisols which have a higher soil water retention due to high accumulation of clay in the lower horizons compared with the Ferralsols in Eldoret. Ferralsols have low water retention capacity, that may lead to stress during dry spells (Jones *et al.* 2013). Regardless of the sites, fertilizer NP treatments had higher biomass yields (6.8 t ha⁻¹) compared to 5.8 t ha⁻¹ in the unfertilized grasses.

Kitale

The shoots biomass were significantly influenced by the grass cultivars ($P = 0.001$) but not by fertilizer NP ($P = 0.26$) and no significant interaction between cultivars and fertilizer NP ($P = 0.57$) were noted during the dry season in Kitale. The lack of response to fertilizer NP during the dry season can be attributed to low nutrient uptake due to low moisture. Among the *Brachiaria*

grasses, Basilisk, MG4 and Marandu accumulated the highest shoots biomass which ranged from 8.9 to 11.2 t ha⁻¹ and was significantly higher ($P = 0.05$) than the commonly grown Rhodes grass while cvs. Llanero and Mulato II had the lowest shoots biomass (Table 2). However, Napier grass produced between 56 to 106% higher biomass compared with the highest yielding Brachiaria cultivars (Basilisk and MG4) during the dry season. In the wet season, Xaraes and MG4 had the highest biomass yields (16 t ha⁻¹) followed by Basilisk > Mulato II > Piata > and Marandu (Table 2). All the Brachiaria cultivars except Llanero produced significantly higher yields than Rhodes grass, while Napier grass out yielded all the grass varieties in the wet season.

Table 2 Shoots biomass of Brachiaria cultivars, Rhodes grass and Napier grass during the dry and wet seasons in Kitale.

Grass cultivars	Dry season	Wet season
<i>B. decumbens</i> cv. Basilisk	11.3b	14.4b
<i>B. humidicola</i> cv. Llanero	3.8d	8d
<i>B. brizantha</i> cv. Marandu	8.9c	12.4c
<i>B. brizantha</i> cv. MG4	10.4b	15.6b
<i>B. hybrid</i> cv. Mulato II	4.6d	14.1c
<i>Pennisetum purpureum</i> cv KK1	17.8a	24.5a
<i>B. brizantha</i> cv. Piata	8.1c	13.6c
Rhodes grass	6.6cd	11.2d
<i>B. brizantha</i> cv. Xaraes	8.6c	15.8b
Mean	8.9	14.42
SED	1.5	1.82
P _(CV)	***	***
P _(NP)	NS	*
P _(CV*NP)	NS	NS

Where- SED- Standard error of difference at $p \leq 0.05$; NP- fertilizer applied at 40 kg P ha⁻¹ and 50 kg N ha⁻¹ per season; CV – cultivar, NS- Not significant at $p \leq 0.05$. Means followed by the same letter for a parameter are not significantly different at $P \leq 0.05$. Mean separation was done by Tukeys HSD test.

During the wet season, all the treatments where N and P was applied produced significantly higher shoots biomass ($P=0.05$) than those with no fertilizer application (Figure 1). Generally, application of fertilizer NP produced 17% higher shoots biomass than the unfertilized treatments. Among the Brachiaria grasses, MG4 and Xaraes had the highest responses to fertilizer NP with 44.7 and 34.8% increase in yields due to fertilizer addition respectively. These cultivars developed chlorosis in treatments without NP fertilizer throughout the season, while the fertilized treatments showed N deficiencies two months after N application particularly during the high rainfall periods. This indicates that cvs. MG4 and Xaraes had higher N demand than the other cultivars which may not have been satisfied by the rate applied. The cvs. Mulato II, Basilisk and Marandu did not respond to application of NP, and were ever green throughout the season. In grasses, N has a major role in chlorophyll formation and increased vegetative growth, while P is important in roots development. The site had low initial soil N (Table 1); therefore, the grasses with little or no response to NP application could be more efficient in N

utilization thereby requiring low N application. Xaraes and MG4 and require N and P fertilization in NP deficient sites to achieve increased production.

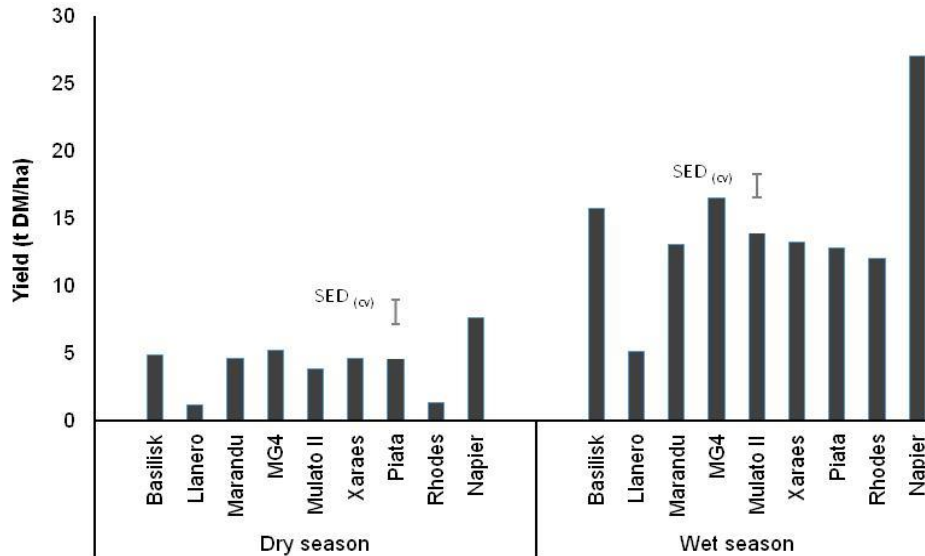


Figure 1 Influence of fertilizer NP on shoots biomass of Brachiaria grasses during the dry and wet seasons in Kitale. Where: cv- cultivar; SED- standard error of difference at $P < 0.05$

Nutritive quality of grass cultivars in Kitale

Generally, the Brachiaria varieties had significantly higher crude protein than the control grasses (Table 3). Mulato II accumulated the highest amounts of crude protein, followed by Basilisk, Piata and Marandu. Cultivars Llanero and MG4 had the lowest crude protein and were comparable to Napier and Rhodes grass (Table 3). Although Napier grass yield was high in both seasons, its nutritional value was lower than that of the Brachiaria grasses. However, the nutritional values were higher than those reported elsewhere by (Paulino *et al.*, 2011) probably due to the geographical location and environmental conditions for the site. Crude protein is higher, in fodder grown in high rainfall areas while structural carbohydrates (NDF) in the grasses is lower (Peterson *et al.*, 1988).

Eldoret

In Eldoret no significant fertilizer ($P \leq 0.05$) effect on shoots biomass was noted in the dry and wet seasons despite the low N and available P content in those soils (Table 1). However, the biomass yields were significantly ($P = 0.001$) influenced by the grass cultivars in the dry season. All the Brachiaria cultivars except cv. Llanero produced similar yields that were significantly ($P = 0.05$) higher than those of Rhodes grass (Figure 2). Napier grass out-yielded all the grasses and accumulated between 2.4 to 6.5 t ha⁻¹ more shoots biomass than the lowest and highest yielding Brachiaria grasses. During the wet season, the biomass yields were influenced by the grass cultivars, but no interaction between the grass cultivars and fertilizer NP occurred. The cvs. MG4 and Basilisk accumulated the highest shoots biomass (14 t ha⁻¹), which was significantly

($P=0.05$) higher than that of other Brachiaria cultivars and Rhodes grass. However, cvs. Marandu, Piata, Xaraes and cv. Mulato II yielded shoots biomass that was similar to that of Rhodes grass, but higher than cv. Llanero (Figure 2). Napier grass out-yielded all the grasses during this season. The high biomass yield accumulated by cvs. MG4 and Basilisk in the dry and wet seasons in the Eldoret site suggest that these are the best bet Brachiaria cultivars.

Table 3 Crude protein (CP), neutral detergent fibre (NDF), and acid detergent fibre (ADF) (% of DM) of Brachiaria grasses at 22 weeks after emergence in Kitale

Cultivar	CP	NDF	ADF
<i>B. decumbens</i> cv. Basilisk	16.5ab	59.8d	37.6c
<i>B. humidicola</i> cv. Llanero	13.6c	66.9a	41.9a
<i>B. brizantha</i> cv. Marandu	15.1ab	59.9d	39.6ab
<i>B. brizantha</i> cv. MG4	12.6c	59.4d	36.8c
<i>B. hybrid</i> cv. Mulato II	17.3a	59.1d	40.6ab
Napier grass	13.1c	64.6b	42.9a
<i>B. brizantha</i> cv. Piata	16.1ab	61.4c	37c
Rhodes grass	14ab	62.7bc	39.3ab
<i>B. brizantha</i> cv. Xaraes	14.91	61.78	39.5
SED	0.88	0.98	1.06
P(CV)	***	***	***

Where- SED- Standard error of difference at $p \leq 0.05$; CV- cultivar; Means followed by the same letter for parameters are not significantly different at $P \leq 0.05$.

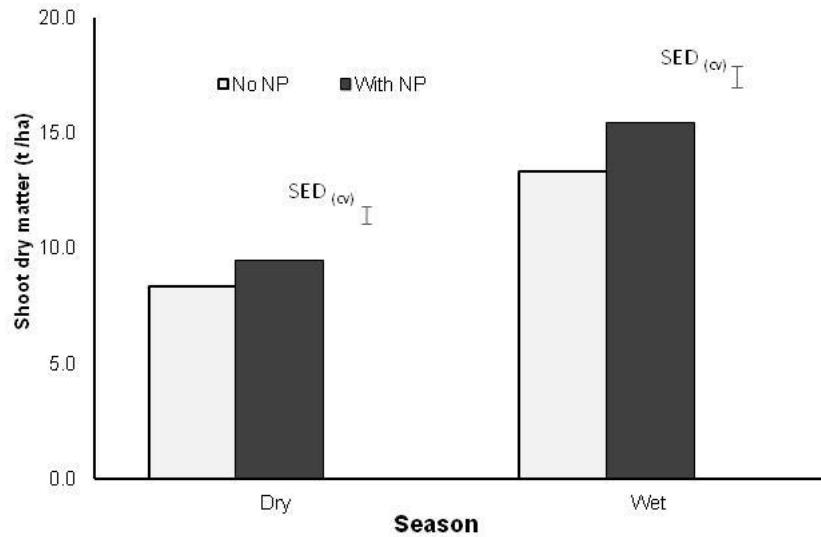


Figure 2 Shoots biomass yields of Brachiaria cultivars, Rhodes grass and Napier grass during the dry and wet season in Eldoret

Kitale

Roots biomass is important in maintaining soil fertility due to its contribution to C and N sink and as a source of exudates for microbial growth resulting to increased microbial activity within the rhizosphere. Application of fertilizer NP had no effect on roots biomass in all sampling periods. The lack of fertilizer response in roots biomass is partly attributed to low NP rates (40 kg P ha⁻¹ and 100 kg N ha⁻¹) that may not have been responsive in these P deficient soils (Table 1). Other studies on effects of fertilization on roots biomass have noted similar results. Kibet *et al.* (2016) for example found no responses to fertilizer N by switch grass fertilized for 4 years, while Jung *et al.* (2011) reported increased above ground biomass due to N application but no changes in roots biomass of switch grass. In the current study, accumulation of roots biomass differed across the two depths sampled with 70% of roots biomass located in the 0-15 cm depth. Roots biomass increased with age but reduced with depth. The highest roots biomass was recorded at 80 WAE (Table 4).

At 22 WAE, Basilisk, Piata and Xaraes had comparable roots biomass in the 0-15 cm depth, which was higher than that of Rhodes and Napier grass while cvs. Llanero and Mulato II accumulated the lowest roots biomass. The roots system of Basilisk consists of finer and longer roots than some other Brachiaria species providing superior uptake of P and N from the soil. Most of the grasses had very low biomass at the subsoil level (15 - 30cm) at 22 WAE. Piata had the highest roots biomass at the 15 - 30 cm depth which was between 80 – 200% higher than the other grasses. Less abundant roots biomass accumulation was noted in Mulato II, Llanero, Napier and Rhodes grass at the lower depth (Table 4).

At 80 WAE, no varietal or fertilizer differences were noted on roots biomass at both the top and lower level but generally, the grasses had higher roots biomass at the 0 - 15 cm depth. Roots biomass was 10 times higher in the 15 - 30 cm depth from soils sampled 80 WAE compared to those sampled 22 WAE, showing that as the growth period increased, more roots were distributed in the deeper horizons. By this period, the varieties may have attained near maximum lateral growth and utilized most of the soil area available for growth thereby investing more roots growth at the lower soil depths. This is important for C sequestration, since most of the C stored in the roots at the deeper horizons contribute to C sink and is better protected from degradation. At the 80 WAE, the Brachiaria grasses had higher roots biomass at the lower horizons than the controls, Napier and Rhodes grass, making Brachiaria a better alternative for soil fertility restoration.

Roots biomass had a significant site x cultivar interaction ($P < 0.001$) at the 22 WAE period in both depths. MG4 had the highest roots biomass in Eldoret (1445 kg ha⁻¹) while Xaraes, Piata and Basilisk had higher roots biomass than other grasses in Kitale at the 0-15 m depth. The grasses differed in roots spread beyond the 15 m depth in both sites. At the 15- 30 m depth, roots biomass ranged from 113 to 438 kg ha⁻¹ in Kitale and 144 to 460 kg ha⁻¹ in Eldoret. A significant varietal effect ($P < 0.001$) was noted in roots biomass production in Eldoret. In general,

all the Brachiaria cultivars had higher roots biomass than the control grass (Napier grass). At 22 WAE, Rhodes grass had not yet fully established due to slow germination and growth in this site, sampling was not done. The cv. MG4 accumulated the highest roots biomass (1445 kg ha⁻¹) while Napier grass had the lowest roots biomass (345 kg ha⁻¹) in this site (Figure 3). As was observed in the Kitale site, roots biomass in all cultivars decreased with sampling depth, and was higher in the 0 - 15 m and lowest at the sub soil (15 - 30 m). Beyond the 15 m depth, Xaraes accumulated the highest roots biomass while Mulato II and Basilisk had the lowest accumulation of roots biomass at this depth.

Table 4 Roots Biomass (kg ha⁻¹) of Brachiaria grasses, Napier grass and Rhodes grass at two depths and three sampling periods in Kitale

Grass cultivars	0-15cm			15-30 cm		
	22WAE	46WAE	80WAE	22WAE	46WAE	80WAE
<i>B. decumbens</i> cv. Basilisk	1192a	2951b	8754a	231b	806a	2739a
<i>B. humidicola</i> cv. Llanero	306b	2225bc	9030a	113c	597a	3335a
<i>B. brizantha</i> cv. Marandu	668b	2330b	8483a	264b	853a	1517a
<i>B. brizantha</i> cv. MG4	710b	2567b	7318a	215bc	848a	2649a
<i>B. hybrid</i> cv. Mulato II	579b	2367b	9175a	113c	1059a	1929a
<i>B. brizantha</i> cv. Xaraes	1338a	2570b	8390a	247b	670a	2454a
<i>B. brizantha</i> cv. Piata	1324a	3150a	8964a	438a	839a	3504a
Rhodes grass	614b	2634b	4332a	140c	658a	1422a
Napier grass	466b	2876b	6986a	195c	804a	1491a
Mean	772.4	2499.5	7791	208.1	764.2	2408.9
SED (cultivar)	232.5	449.1	NS	68.1	NS	NS

WAE- weeks after emergence; cv – cultivar, NS- not significant at $P \leq 0.05$. Means followed by the same letter for a parameter are not significantly different at $P \leq 0.05$. Mean separation was done by Tukeys HSD test.

Increased roots biomass is essential in plant productivity because in grasses, high roots biomass improves nutrient and water uptake (Bowman *et al.*, 1998) particularly during periods of water scarcity. Xaraes, MG4, Piata and Basilisk had high roots biomass in both sites and accumulated higher shoots biomass than the other grasses especially during the dry season. Biomass investment in shoots and roots differed between Napier grass and the Brachiaria cultivars. Napier grass invested up to 20 times more biomass in shoots than roots in Kitale and nearly 10 times in Eldoret. The lower investment in Kitale would be due to sufficient moisture which encouraged higher shoots growth at the expense of roots. In Eldoret, soil depth and moisture was limiting leading to higher roots biomass to scavenge for water and nutrients. The Brachiaria cultivars had comparatively lower investment in shoots: roots biomass, which ranged between 1.2 to 2.1 and 2.5 to 5.0 in Eldoret and Kitale, respectively.

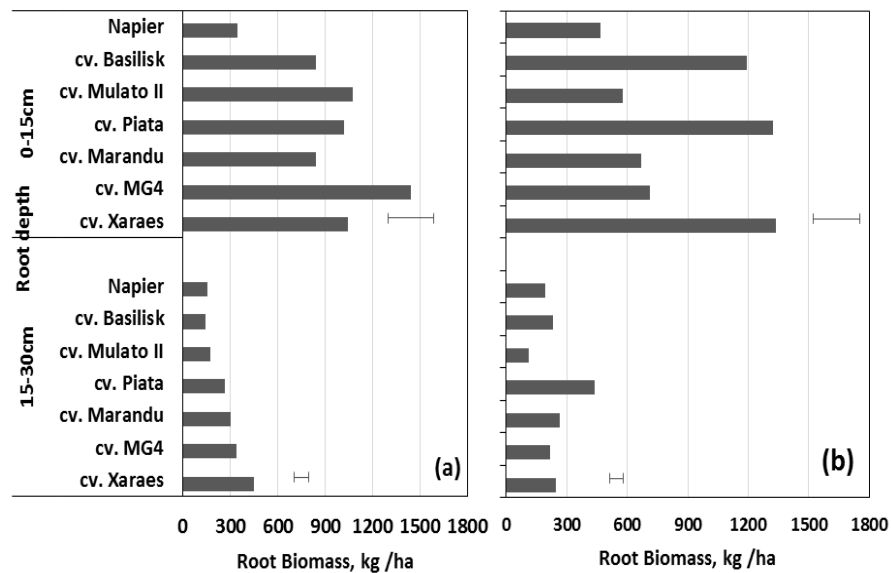


Figure 3 Roots Biomass (kg ha⁻¹) of Brachiaria grasses and Napier grass at different sampling depths in Eldoret (a) and Kitale (b). Bars represent LSD P<0.05.

Relationship between shoots biomass yields and growth parameters

In Kitale, shoots biomass was strongly and positively correlated with plot cover and plant spread ($P=0.001$) and was also positively but weakly correlated with plant height (Table 5). Cultivars that had wider spread and high plot cover such as Basilisk and MG4 accumulated higher biomass during the dry season. The number of tillers and roots biomass did not influence the shoots biomass in the dry season.

The relationship between grass growth parameters and shoots yield in Eldoret are shown in Table 6. It was observed that during the dry season, shoots biomass was dependent on plant spread, height and cover but had no relationship with plant height, tiller density or roots biomass. A significant linear relationship ($R^2 = 0.491$; $P = 0.001$) was observed between plant spread and shoots biomass. Plot cover plays a major role in soil and water conservation. In this study, Basilisk, MG4, Xaraes and Piata were more decumbent, with high spread and plot cover (60%) thereby accumulating higher biomass in the dry season. However, the erect grasses, Rhodes grass and Mulato II had low plot cover (45%), and plant spread (24 m), which contributed to lower shoots biomass during the dry season. Mganga (2009) reported similar results, with *Cenchrus ciliaris* producing higher biomass among four local grasses due to increased horizontal spread. During the wet season, grass spread, cover and height were the most important growth parameters influencing shoots biomass, with spread and cover having the highest significant linear relationship with shoots biomass in Eldoret (Table 6). Therefore, the grasses that had more spread and higher plot cover accumulated more biomass including MG4 and Basilisk.

Table 5 Pearson correlations between grass growth parameters and shoots biomass yield during the dry and wet season in Kitale

		Shoots biomass	Tillers	Height	Spread	Plot cover	Roots biomass
Dry season	Shoots biomass	1					
	Tillers	-0.289	1				
	Height	0.435***	-0.6789***	1			
	Spread	0.605***	-0.118	0.452***	1		
	Plot cover	0.613***	-0.165	0.0956	0.417***	1	
	Roots biomass	-0.027	0.096	-0.271*	-0.312	0.002	1
Wet season	Shoots biomass	1					
	Tillers	-0.113	1				
	Height	0.441***	-0.725***	1			
	Spread	0.245*	0.676	-0.525***	1		
	Plot cover	0.501***	-0.034	0.325**	0.216	1	
	Roots biomass	-0.019	-0.098	0.626*	-0.067	0.129	1

Where * - $P \leq 0.05$; ** - $P \leq 0.01$; *** - $P \leq 0.001$

Table 6 Pearson correlation coefficients showing relationship between grass growth parameters and shoots biomass yield during the dry and wet season in Eldoret

		Shot biomass	Tillers	Height	Spread	Plot cover	Roots biomass
Dry season	Shot biomass	1					
	Tillers	0.792	1				
	Height	0.191	0.474***	1			
	Spread	0.491***	0.577***	0.485***	1		
	Plot cover	0.564***	0.658***	0.385**	0.285*	1	
	Roots biomass	0.385	0.264	0.069	0.084	0.195	1
Wet season	Shot biomass	1					
	Tillers	0.067	1				
	Height	0.488***	-0.470***	1			
	Spread	0.700***	0.191	0.115	1		
	Plot over	0.849***	-0.135	0.656***	0.608***	1	
	Roots biomass	0.385	0.175	0.156	0.098	0.098	1

Where * - $P \leq 0.05$; ** - $P \leq 0.01$; *** - $P \leq 0.001$

Conclusions

In general, results from this study show that shoots biomass varied considerably depending on the cultivar and the site. Fertilizer NP response was minimal despite the low soil N and P in both sites. The shoots biomass was mainly influenced by the spread and plot cover attributes both in the dry and wet seasons. Brachiaria cultivars out-yielded Rhodes grass, the commonly grown grass in the region and accumulated high roots biomass in early establishment phase.

Basilisk and MG4 and may be considered as the best bet cultivars for the north western highlands region due to their superior biomass yields.

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