Tropical and Subtropical Agroecosystems, 10 (2009): 441 - 449

Tropical and Subtropical Agroecosystems

THE CANOPY EFFECTS OF *Prosopis juliflora* (DC.) AND *Acacia tortilis* (HAYNE) TREES ON HERBACEOUS PLANTS SPECIES AND SOIL PHYSICO-CHEMICAL PROPERTIES IN NJEMPS FLATS, KENYA

[EFECTO DEL DOSEL DE *Prosopis juliflora* (DC.) Y *Acacia torticolis* (HAYNE) SOBRE LAS HERBACEAS Y CARACTERÍSTICAS FÍSICO-QUÍMICAS DEL SUELO EN LAS PLANICIES NJEMPS, KENYA]

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SUMMARY

The canopy effects of an exotic and indigenous tree species on soil properties and understorey herbaceous plant species were investigated on the Njemps Flats, Baringo district, Kenya. Samples of soil and herbaceous plant species were obtained within the canopies of systematically selected *P. juliflora* (exotic) and *A. tortilis* (indigenous) trees, and from adjacent open areas. Standing biomass, frequency and cover of understorey plant species were significantly (P<0.05) higher in the open area than under the canopies. Cover for herbaceous plant species was 63% under *P. juliflora*, 82% under *A. tortilis* and 90% in open areas. All forbs occurred under the canopies indicating that they are more adapted to the shaded microenvironments than grasses. Soils under the tree canopies had significantly (P<0.05) higher organic carbon and total nitrogen than those in adjacent open areas. Soils under *A. tortilis* had significantly (P<0.05) higher organic carbon and total nitrogen than soils from under *P. juliflora*. The results suggested that *A. tortilis* trees are more beneficial to soil physical and chemical properties than *P. juliflora*. Accordingly, the common practice of clearing woody trees indiscriminately to improve grassland for livestock production or for crop cultivation should not be recommended.

Key words: *Prosopis juliflora; Acacia tortilis*; canopy cover; herbaceous layer; soil properties; Kenya.

RESUMEN

Se investigó el efecto del dosel de un árbol nativo y uno exótico sobre las propiedades del suelo y vegetación herbacea debajo del dosel en las planicies Njemps, Kenya. Se tomaron muestras de suelo y herbaceas dentro del área del dosel de árboles de *P. juliflora* (exótica) y *A. torticolis* (nativa), Así como de áreas abiertas adyacentes. Biomasa, frecuencia y cobertura de las herbaceas fue mayor en las áreas abiertas (P<0.05). La cobertura fue 63% debajo de *P. juliflora*, 82% en *A. torticolis* y 90% en áreas abiertas. Todas las herbaceas estuvieron presentes debajo del dosel de los árboles indicando una mejor adaptación a microambiente de sombra en relación a los pastos. En relación al área abierta, el suelo en el área del dosel tuvo un mayor contenido de carbono orgánico y nitrógeno total (P<0.05) y estos fueron más elevados debajo del dosel de *A. torticolis* (P<0.05). Los resultados sugieren que los *A. torticolis* produce mejores beneficios en las propiedades físicas y químicas de los suelos. Se sugiere que la práctica de eliminación indiscriminada de árboles de las prades para la ganadería y/o cultivos agrícolas no debe ser recomendada.

Palabras clave: *Prosopis juliflora; Acacia torticolis;* dosel; herbaceas; propiedades del suelo; Kenya.

INTRODUCTION

In Africa, savannahs are characterised by the presence of a continuous graminoid stratum and a discontinuous woody stratum that forms the upper canopy of the vegetation (Menault *et al*. 1985). Shrubs and trees take water and nutrients from deep soils, which is beneficial to the herbaceous plants species. Thus, removal of trees from the savannah ecosystems, which usually have alternating wet and dry season and often support large numbers of grazers, could endanger the survival of the shallow rooted herbaceous plants during the dry periods, as they are unable to access water from the deep soil horizon. Benhard-Reversat (1982) concluded that trees are an important ecological component that maintains soil fertility as a result of nitrogen fixation and accumulation of organic matter through litter fall.

From early 1970's the effects of trees on their understorey environments have received increasing attention as range scientists investigate the effects of the interaction of woody plant species and herbaceous plants in rangelands. These studies have been conducted in a wide variety of ecosystems, with various tree and herbaceous plant species, often with different results. Belsky *et al*. (1989), working in Tsavo National Park, Kenya, noted that in areas of low tree densities, moderate or high soil fertility, and low rainfall, trees might increase forage production. Young (1989) found substantially higher organic matter under canopies of *Adansonia digitata* (Linn.) and *Acacia tortilis* (Forsk) than in the adjacent open area in the semi-arid areas of Tsavo National Park, Kenya. Tiedmann and Klemmedson (1973), working on American rangelands reported that soils under canopies of mesquite trees *(Prosopis* spp*)* were more fertile than those in the open areas. In contrast, Ellison and Houston (1958) noted an inverse relationship between the tree canopy and herbaceous understorey production. Similar results were observed by Engel *et al.* (1987) who reported a substantial reduction in herbage production under and around *Juniperus virginiana* L. in north-central Oklahoma.

The effects of trees on associated understorey herbaceous productivity vary with the species and environment (Burrows 1993). Jetsch *et al*. *(*1996) indicated that different herbaceous plant species will respond differently to different types of tree canopies and that the function of savannah trees might vary with the population density and distribution. The foregoing results are relatively area and plant-specific and results from one area with specific tree species cannot be extrapolated to other areas with different tree and herbaceous plant species. Therefore, research findings cannot be generalised for all sites with different grass and tree species, soil type and climates. Few studies on tree understorey parameters and dynamics so far conducted in southern and central Kenya rangelands have only involved a few tree species. These rangelands support wide variety of trees and grasses.

Based on the few studies so far published and the little quantitative information available on the woody plant species of tropical arid and semi-arid areas, and their effects on understorey plants, it is apparent that the interaction between trees and their understorey herbaceous plants is far from being well understood. This study was therefore, conducted to evaluate the effects of *Prosopis juliflora* (an exotic and invasive) and *Acacia tortilis (*an indigenous tree species) trees on herbaceous plant species and soil properties in the lowlands of Njemps Flats, Baringo District, Kenya.

MATERIALS AND METHODS

Study area

The Njemps Flats range unit is located between 1°45' and 0°15' northern latitude and 35°45' and 36°30' eastern longitude in the Baringo District of the Eastern Rift Valley in Kenya, and covers approximately 305 km². It is one of the district's 11 range units, characterised by a unique combination of altitude, precipitation, soil and vegetation. This flat to slightly undulating plain, west of Lake Baringo, has an average altitude of 900 m a.s.l. (Herlocker, 1994) and is surrounded by high altitude Tugen hills, ridges and plateaus of the Lake Baringo catchment, having peaks over 2,300 m (Thom and Martin, 1983). The area falls within ecological zone IV, classified as semi-arid by Pratt and Gwynne (1977). Total annual rainfall range is 300-700mm described as low, unreliable and highly localized (Ekaya *et al*., 2001), characterised by a bimodal rainfall distribution with two peaks in April and November. Annual evapo-transpiration potential is 1600-2300mm indicating 1000-1400mm moisture deficit. Analysis of a time series of rainfall records in the Njemps Flats by Kipkorir (2002) revealed a decrease in the number of rain-days with time, while the rainfall amounts stayed unaltered, inferring an increase of the rainfall intensity on the rainy days, separated by longer periods of drought. The temperature shows little variation throughout the year with mean monthly temperatures ranging from 24 to 26°C (Ekaya *et al*., 2001; Kipkorir, 2002). Major economic activity is livestock grazing by the agro-pastoral communities inhabiting the area.

Methods

Soils and herbaceous plant species under *Acacia tortilis* and *Prosopis juliflora* trees were compared with each other and with soils and herbaceous plants species beyond the canopies. Five mature *P. juliflora* and *A. tortilis* trees of similar canopy size (≅ 8m diameter) and structure, without shrubs or termite mounds under or close to their canopy and growing under similar conditions (soil type and terrain), were systematically selected for the study. Each *A. tortilis* had a similarly isolated *P. juliflora* tree 20-30m away across a level ground. Under each *A. tortilis* and *P. juliflora* tree, sampling points were selected 1m, 2m and 3m from the tree trunk and 4m, 5m and 6m from the edge of tree canopy, along the four cardinal directions around the tree trunk. Soil samples were obtained at 0-5cm, 15-20cm and 40-45cm depths along each of the four cardinal directions at the sampling points. Enclosures were erected around all the experimental trees and adjacent open area at the beginning of February 2001 to keep off livestock.

For each tree or experimental unit, soil samples at each of the three depths and distances were combined to produce a composite sample for the analysis. For each pair of *P. juliflora* and *A. tortilis* trees, soil samples from the open areas were further composited into one sample as the area was uniform in terms of slope, soil type and ground cover. Aluminium cylinders (5cm diameter) were used to extract undisturbed soil core samples for soil bulk density determination. Core rings were hammered into the soil and carefully removed. The soil samples were oven-dried at 70^{o}C for 24 hours and analysed at the Soil Science department, University of Nairobi, using the following techniques: Organic carbon was determined using the Walkley-Black method as outlined by Black *et al*. (1965); total nitrogen was determined by the wet digestion method of Bremner (1965); available soil phosphorus was determined using the double acid method described by Mehlich (1962). Soil pH was determined using the method described by Peech (1965). The soil cores for bulk density were oven dried at 105^{o}C for 24 hours, weighed and bulk density was computed following equation 1.

$$BD\ (cm^{-3}) = [WOS\ (g)/\ VC\ (cm^3)]*100 \qquad (1)$$

Where:
BD = Bulk density,
WOS= weight of oven dry soil,
VC= volume of corering.

Aboveground standing crop biomass of herbaceous plant species within and outside the canopy

Sampling of herbaceous plants was conducted in May 2001, two and half months after onset of the long rains when the plants had gained substantial growth. Above ground herbaceous biomass production within and outside the canopies of the two tree species was determined using a 0.25m^2 quadrat. The quadrat was placed at 0-1m, 1-2m and 2-3m intervals from the tree trunk along the four cardinal directions around the tree trunk under the tree canopy. The same procedure was repeated in the open area. The herbaceous vegetation within the quadrat was clipped at 2cm above the ground level to avoid soil contamination. The fresh plant materials were stored in labelled paper bags and later oven dried to a constant weight at 70^{o}C for 48 hours. Aboveground biomass yield was expressed in ton.ha^{-1} on dry matter basis.

Basal cover was estimated by the ten-pin point frame method described by Levy and Madden (1933). The frame was placed at each of the three sampling points under the canopy and in the open area.

Nine plots were sampled under each tree and in the open area along the established radii. The mean basal cover from four plots within and outside the canopy, at each of the designated points along the four cardinal directions, was determined. For each pair of *A. tortilis* tree and *P. juliflora* tree, an average of twenty-four sampling points outside the canopies of two trees was calculated. Samples of herbaceous plant species from open areas of each pair of the tree species were pooled. The samples were pooled because the study site was uniform in terms of land terrain and vegetation cover and that each pair of the tree species was 20-30m away from each other. Percent plant cover was computed using equation 2.

$$Total\ cover = (TI\ /TP) * 100 \qquad (2)$$

Where:
TI = total number of intercepts,
TP = total number of pins.

Percent frequency of herbaceous plants was also determined by means of a ten pin point-frame. The number of intercepts on a given plant species was recorded. The percent frequency of each herbaceous plant species was calculated using equation 3.

$$Frequency\ (\%) = (NISG/TIAS)*100 \qquad (3)$$

Where:
NISG = Number of intercepts of a given species, TIAS= total number of intercepts of all species.

Data on percent herbaceous biomass, cover, species frequency, soil carbon, total nitrogen, available phosphorus, pH and soil bulk density were subjected to analysis of variance (ANOVA) with a complete random design, after Steel and Torrie (1980). The ANOVA model used was Y_{ij}= U + $T_{i(1-3)}$ + E_{ij} Where: U= overall mean, i(1-3) = mean of samples obtained below the canopy of 1-*P. juliflora*, 2-*A. tortilis*, 3-obtained in open area, E_i- residual error with (μ=0; e=1 o 2). The ANOVA was conducted using sample means. Sources of variation in the analysis were the tree species, tree canopies and the open area. Where significant differences were detected, means were separated using least significance difference (LSD) according to Steel and Torrie (1980).

RESULTS

Aboveground net primary production, cover and frequency of herbaceous plant species within and outside tree canopies

The mean net primary production, cover and relative frequency of herbaceous plant species within and outside the canopies of the two trees is presented in Table 1. The results showed a significant (P<0.05) difference in biomass production between the open and shaded areas for both trees, with the higher biomass yield being found in the former than the latter area for both trees. The average herbaceous biomass yield was more than twice under *A. tortilis* canopies than under the canopies of *P. juliflora*. The open area had a significantly (P<0.05) higher herbaceous plants cover than under the canopies of *A. tortilis* and *P. juliflora* respectively.

Cynodon dactylon was the most dominant grass species in both open area as well as under the canopies of *P. juliflora* and *A. tortilis* respectively (Table 1). Results indicated a high concentration of herbaceous plant species under the canopy than in the open areas. The dominant herbaceous plant species under *P. juliflora* canopy were *C. dactylon*, *Setaria verticilata*, and *Cyperus rotundus*, while under *A. tortilis* these were *C. dactylon*, *Eriochloa meyrianum*, *Setaria verticilata* and *C. rotundus*. There was a higher composition of herbaceous plant species under *P. juliflora* canopy than under *A. tortilis* canopy. Frequency data showed that there were more grass species under the *A. tortilis* canopy than under *P. juliflora* canopy. *Acantherspermum hispidum* and *Amaranthus spinosa* forbs were present under the canopies of the two trees but not in adjacent open areas while *Mormodica foetida* and *Polygonum setbsum* forbs occurred only under *P. juliflora.*

Soil organic carbon, total nitrogen, available phosphorus, pH and bulk density within and outside the canopy

Soil organic carbon, total nitrogen, available phosphorus, pH and bulk density data is presented in Table 2. Organic carbon content and total soil nitrogen content was significantly (P<0.05) higher under canopies of both trees than outside the canopy. Soils under *A. tortilis* canopy had twice as much total nitrogen as the soils in the adjacent open areas and more than one and half times than soils under *P. juliflora*.

Table 1. Mean and standard deviation of net primary production (t ha^{-1}), ground cover (%) and relative frequency (%) of herbaceous plant species under *P. juliflora.* and *A. tortilis* canopies and open areas.

Parameter	*Prosopis juliflora*	*Acacia tortilis*	Open area
Cover (%)	63±12.87^{c}	82±7.08^{b}	90±1.81^{a}
Net primary production (t ha^{-1})	0.65±0.02^{c}	1.33±0.3^{b}	3.36±0.96^{a}
Relative frequency (%)			
Grasses			
Cynodon dactylon	68.9^{b}	49.6^{c}	97.2^{a}
Setaria verticilata,	9.4^{b}	14.6^{a}	0.0^{c}
Eriochloa meyerianum	0.0^{b}	18.3^{a}	0.0^{b}
Grasses sub-total	**78.3^{a}**	**82.5^{a}**	**97.2^{b}**
Forbs			
Acantherspermum hispidum	3.1^{a}	2.6^{a}	0.0 ^{b}
Amaranthus spinosa,	3.1^{a}	2.6^{a}	0.0 ^{b}
Polygonum setbsum	3.1^{a}	0.0^{b}	0.0^{b}
Mormodica foetida	3.1^{a}	0.0^{b}	0.0 ^{b}
Forbs sub-total	**12.4^{b}**	**5.2^{b}**	**0.0^{c}**
Sedges			
Cyperus rotundus	9.4^{b}	12.3^{a}	2.8^{c}
Sedges sub-total	**9.4^{b}**	**12.3^{a}**	**2.8^{c}**
Grand Total	100	100	100

Means on the same row with different letter superscript are significantly different (P<0.05)

Table 2. Mean and standard deviation of organic carbon (%), total nitrogen (%), available phosphorus (%), pH, and bulk density (g cm^{-3}) within and outside tree canopies and in open areas.

Attribute	Prosopis juliflora	Acacia tortilis	Open area
Percent organic carbon	1.23±0.13^{a}	1.37±0.30^{b}	1.09±0.15^{c}
Percent total nitrogen	0.08±0.04^{b}	0.13±0.07^{a}	0.06±0.02^{c}
Available Phosphorus (ppm)	664±98.8^{c}	675±41.3^{b}	722±175.0^{a}
Soil Ph	7.08±0.43^{b}	7.16±0.09^{b}	7.48±0.09^{a}
Bulk density (g cm^{-3})			
0-5cm soil depth	1.16^{b}	1.18^{b}	1.28^{a}

Means on the same row with different letter superscript are significantly different (P<0.05)

Available phosphorus was significantly (P<0.05) higher in the open areas than under the canopies of both trees. Soils under *A. tortilis* had 2.2% more phosphorus than those under *P. juliflora* canopies. We observed a significant (P<0.05) difference in pH between the soils within and outside the canopies of both trees, with a higher pH being found in the open than under the canopy areas. Soil pH under the canopies of the two tree species was not significantly (P<0.05) different

DISCUSSION

The lower total biomass production under the tree shades than in open areas indicate canopies inhibit production of understorey plant species with *P. juliflora* having more negative effects than *A. tortilis*. Visual inspection of the two tree species canopies shows a distinct difference in physical structure. *A. tortilis* crowns are shallower and more hemispherical in shape while *P. juliflora* crowns are deeper and more globular, giving rise to a higher shade intensity that reduces the photosynthetic rates of the understorey herbaceous plants, resulting in lower biomass production. Therefore, the architectural and allometric differences between the canopies of the two tree species may be important factors as far as light transmission to the understorey plant species is concerned.

The results coincides with findings of Frost and Edinger (1991), and Belsky *et al*. (1993) who reported lower biomass production from herbaceous plant species under tree canopies than in the open areas. Carlton *et al*. (1983) noted that as *P. juliflora* becomes established, the herbaceous vegetation cover within the canopy decreases, which he attributed to the rooting pattern and the shading effect of this tree. Tiedmann and Klemmedson (1977) noted that roots of *Prosopis* spp. extend downward and laterally and affect the soil moisture regime under the canopy. Cable (1976) reported that the extensive lateral root systems of *P. juliflora* occupy the same soil horizon as the grasses. The tree extracts water rapidly from the upper part of the root zone close to the tree trunk. The assumption is that the roots of *Prosopis spp* exert a stronger "pull" on the soil water than the grasses. This could also explain the low biomass of herbaceous plant species observed under *P. juliflora* than *A. tortilis* canopy.

The low herbaceous plant species production under both canopies than in the open areas could be attributed to the canopy geometry, which influences the intensity and duration of light received by the understorey plant species. Frost (1990) noted that the shading effect of the evergreen woody species, such as *P. juliflora*, might limit herbage production under their canopies. Weltzin and Coughenour (1990) observed that shading by tree canopies might be the most important factor affecting understorey herbage production and composition in African savannah. Pieper (1990) and Walker *et al*. (1981) argued that apart from reduced light intensity at higher canopy densities, competitive interactions for water and nutrients between trees and herbaceous plant species, could partly account for the low biomass production. In contrast, forbs were more abundant within than outside the canopies. This indicates that forbs require a modified microclimate of lower temperature and lower light intensities, such as is found under tree canopies.

Sen and Sachwan (1970) stated that *P. juliflora* trees inhibit growth of understorey plant species due to phytotoxic effects of their leaves. The observation by Sankhla *et al*. (1965) that *A. tortilis* and *P. juliflora* are alellopathic in nature may also partly explain the relatively low biomass production of herbaceous plant species obtained under the tree canopies. Therefore, selective grazing, phytotoxic effects of leaves, shading and competition for soil moisture are some of the most important factors that might have contributed to the low frequency of grass species under the canopies of *P. juliflora* and *A. tortilis.* Results of this study agree with those of Harrington and John (1990), Belsky *et al* (1993) and Kinyamario *et al*. (1995) who noted that the understorey plant species composition was generally different from that of the area immediately outside the canopy. The authors attributed the differences in herbaceous species composition and frequency to differences in shade density, water stress, and grazing tolerance among the herbaceous species. Wasonga (2001) working in south-central Kenya reported a higher frequency (68%) of herbaceous plant species in the open areas than under the canopy of *Balanites glabra*. Mildbr and Schlecht (29%). Kinyamario *et al.* (1995) attributed the differences in herbaceous plant species composition between the canopy zones and adjacent open grassland to differences in carbon assimilation rates and water use efficiencies among the herbaceous species.

The accumulation of organic carbon and total nitrogen below the tree canopies may be partly due to the earlier seasonality of litter fall and reduced leaching under the tree canopy. The residential herbivores and birds could also be responsible for the higher organic carbon and total nitrogen observed under the tree canopies. The lower organic carbon content in open areas could also be attributed to the fact that the main source of organic matter is grass. Jones (1971) indicated that in grass-dominated savannah soils, residues from the natural vegetation, are usually poor in nitrogen and seem likely to initiate a period of soil nitrogen immobilization when returned to the soil as the grass residues are low in nitrogen:carbon ratio. This may also explain the low total nitrogen obtained in the open areas. The higher organic carbon and total nitrogen level under *A. tortilis* canopy could be attributed to the deciduous nature of the species compared to *P. juliflora*, which is an evergreen tree.

Higher concentration of carbon and nitrogen in the soils within the canopy than in soils in the adjacent open areas has been reported in earlier studies (Garcia-Moya and Mckell 1970, Belsky *et al*. 1989, Dregne 1992, Kinyua 1996 and Wasonga 2001). They attributed this enrichment of carbon and nitrogen under the canopy, to organic matter accumulation and reduced leaching under the tree canopies. These results also corroborate with those of Felker (1978) who reported 50-100% higher organic carbon under the tree canopies. Young (1989) reported substantially higher organic carbon under the canopies of *Adonsonia digitata* Linn. and *A. tortilis* (Forsk) than in the adjacent open areas in Tsavo National Park, Kenya. The high nitrogen and organic carbon of soils *A. tortilis* canopies can be attributed to the semi-deciduous nature of the species and the strong symbiotic relationship with the native soil microbes compared to *P. juliflora* which is an exotic tree that is evergreen.

Tiedemann and Klemmedson (1973), Kellman (1979), Georgiadis (1989), Grouzis and Akpo (1997) noted that the formation of an island of improved soil fertility beneath the tree canopies could be due to accumulation of “top fertile” soil that has been eroded from open areas. Sharma (1985) was of the opinion that the most important source of organic matter and a substantial proportion of the currently available nutrients in the soil is the annual litter falling from the trees. Other exogeneous sources include spatial transfer of nutrients, which may be considerable even under normal grazing practices. Miyazaki *et al*. (1987) for example, reported that under temperature of around 27^{o}C, 44-53% of urination and 26-29% of defecation by herbivores, particularly cattle, occur in the shade.

Trees also act as windbreaks resulting in loose organic debris swept from areas between trees being trapped and retained beneath the tree canopies. The enhanced soil fertility under the two tree species can be accounted partially by the decomposition of these materials. Menault *et al*. (1985) argued that root turnover is probably more important than litter accumulation in improving the soil fertility status within the canopy zone. Therefore, the higher amount of soil nutrients found under tree canopies may as a result of litter and roots decomposition, biological processes such as nitrogen fixation and dung deposition from mammals.

The lower available phosphorus content under both tree canopies in this study could be attributed to biological processes that are continuously taking place between the Rhizobium bacteria and the tree roots, as both tree species are leguminous. Rhizobium bacteria are utilize the phosphorus in synthesising their proteins and hence the low level of it under the canopies. The results of this study are consistent with those of Young (1989) who also observed low phosphorus in sub-canopy zones and attributed it to being utilized in biological nitrogen fixation by the Rhizobium bacteria.

Soils under the canopy tended to be more acidic than soils in open areas. The slight acidity of the soil within the canopy zone could be attributed to leaches and exudes from litter fall and roots. The findings of this study are in agreement with those of Bhatia *et al*. (1998) who observed a significant reduction in the soil reaction (pH) under the canopies of *P. juliflora*, but inconsistence with the findings of Dunham (1991) reported that soils were less acidic within than outside the canopies.

The lower soil bulk density observed under the tree canopies than in the adjacent open areas could be attributed to tree canopies that protect the soil from the force of raindrops. The high bulk density in the adjacent open area could be attributed to increased soil compaction as result of animal activities or raindrop effect. *Prosopis juliflora* and *A. tortilis* trees have lateral roots, some running close to the surface. *Prosopis juliflora* is evergreen, which ensure that the soil is protected from the action of raindrop at any given time. Other studies have reported lower soil bulk density beneath tree canopies than in adjacent open areas (Tiedemann and klemmedson 1973, Haworth and Mcpherson 1995). The lower bulk density within the canopy could be due to improved macroporosity (Joffre and Rambal 1988). Conversely, higher bulk densities could be as a result of trampling by large animals seeking shade or forage (Federer *et al*. 1959 and Warren *et al*. 1986).

There is an indication that *P. Juliflora* and *A tortilis* trees are the causal agents of the pattern observed in the soil analysis and that they function to improve the soil physical and chemical properties beneath their canopies with the later being more efficient than the former. Therefore, *A. tortilis* trees should be encouraged to grow in grazing lands for improved livestock production.

CONCLUSIONS

P. juliflora and *A. tortilis* trees inhibit herbaceous plant growth under their canopies but increases herbaceous diversity. Inhibition is more pronounced under *P. juliflora* canopy than *A. tortilis* canopy. The results also suggest that forbs are more suited to shaded environment than grass species. Similarly, the canopy zone seemed to hosts a richer species composition than open areas but majority of these species were annuals that have low significance in the management of the arid and semi arid areas for livestock production. There were more herbaceous plant species under *P. juliflora* canopy than *A. tortilis* canopy.

P. juliflora and *A. tortilis* improve the soil organic carbon, total nitrogen and bulk density beneath their canopies. However, *P. juliflora* trees are as efficient at increasing soil fertility as some indigenous tree species like *A. tortilis*. Although the improvements in physical and chemical properties of soils under the canopies might have resulted from the combined inputs of trees and grass litter, the external sources of the nutrients that enrich the soil seem not to be known. The nutrients enriching the canopy-zone soils were likely to have been brought into the zone by the trees, which extract nutrients and water with their roots from deeper and in areas beyond the tree canopies and by birds and large mammals, which transport nutrients from the grassland to the canopy zone in their food and nest materials.

With higher soil total nitrogen and organic carbon under the tree canopies, it would have been expected that there would be improved herbaceous plant species production. However, nutrients are less likely to have been a limiting factor in production of herbaceous plant species under the canopy. Therefore, it is probably competition between the woody plants and herbaceous plant species for soil moisture and sunlight, which resulted in low production of the later within the tree canopy. Moreover, other factors such as allelopathic effects from litter and livestock seeking more fresh and nutritious grass species could have influenced the grass cover and production of biomass within the canopy zone than in the nearby open areas. Additional research is called for to isolate and separate different factors influencing herbaceous biomass production within the canopy zone. Such research could be conducted in different areas with different trees and herbaceous plant species. Data generated would provide adequate information necessary before comprehensive conclusions concerning woody-herbaceous plant interactions in the arid and semi-arid regions.

ACKNOWLEDGEMENTS

This study was made possible through the financial support provided by the University of Nairobi in support of MSc programme in Range Management of the first author at the same University. Special thanks go to the staff of the Land Resources Management & Agricultural Technology Department, University of Nairobi, for kind assistance during the fieldwork and sample analysis.

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Submitted November 18, 2008 – Accepted February 27, 2009
Revised received March 23, 2009