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**RELATIONSHIP BETWEEN TREE DENSITY AND GRASS DRY MATTER YIELD  
IN A SOUTHERN AFRICAN SAVANNA**

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**Abstract**

The investigation was carried out on a densely wooded area in the Mopani savanna of South Africa. Seven plots were subjected to different intensities of tree thinning, ranging from a totally cleared plot (0 %) to plots thinned to the equivalent of 10 %, 20 %, 35 %, 50 % and 75 % of the leaf biomass of a control plot (100 %). The grasses responded positively to the tree thinning in terms of total dry matter yield. The yields between tree canopies were generally of the same order or higher than under tree canopies, with the yields where trees have been removed initially the highest. At high tree densities, yields differed little between seasons of varying rainfall. No quantitative advantages of *C. mopane* trees on the grass layer could be established, and the highest grass DM yields were recorded in plots where all trees were removed. The relationship between grass DM yield and tree density (expressed as Evapotranspiration Tree Equivalents ha<sup>-1</sup>) was curvilinear, best described by the exponential regression equation.

**Keywords:** *Colophospermum mopane*, dry matter yield, leaf volume, grass-tree competition, savanna.

## Introduction

The Mopani savanna is an extensive and important vegetation type of southern Africa. It is perceived that in recent history an increase in tree density occurred, mainly as a result of overgrazing by domestic stock, the elimination of mega herbivores, notably elephants, and the exclusion of sporadic hot fires. The suppressive effect of an increase in tree density on the production of the grass layer is considered as a serious problem by landowners. In an attempt to restore the productivity of grasses, tree clearing/thinning is commonly employed, often at high cost. However, the economical and ecological viability of these practises has not been established. Subsequently, a study on the effect of tree thinning on the productivity of the grass layer was undertaken to establish the relationship between tree density and grass production. Differences in the dry matter yield of grasses within defined subhabitats (under trees, between trees, where trees were removed) were also investigated.

## Material and Methods

The study was conducted in the Northern Province of South Africa on a site located at 29°12'E, 22°19'S, 560 m above sea level. The vegetation is described as Mopani veld (Acocks, 1988) and is dominated by the woody species *Colophospermum mopane*. The most important grass species are Nine-awned Grass (*Enneapogon cenchroides*), Annual Three-awn

(*Aristida adscensionis*), False Signal Grass (*Brachiaria deflexa*), Foxtail Buffalo Grass (*Cenchrus ciliaris*) and Common Finger Grass (*Digitaria eriantha*).

The rainy season extends from October to March inclusive, but rainfall is irregularly distributed and unpredictable. Mean long-term seasonal rainfall (July-June) was 376 mm (SE  $\pm$  27.6, range 140-620 mm). The area is known for its high summer temperatures and moderate to warm winter temperatures. The underlying geology is mainly sandstone, and the soil is sandy (80 % sand, 8 % silt, 12 % clay) with an effective depth of more than 1.2 m. The experimental site consisted of seven, 1.17 ha plots (180 m x 65 m), thinned to differing tree densities. The control plot was left undisturbed (referred to as the 100 % plot), and the others thinned to the approximate equivalents of 75 %, 50 %, 35 %, 20 %, 10 % and 0 % of the tree biomass of that of the 100 % plot (2 711 trees ha<sup>-1</sup>). Herbaceous plants were almost completely absent in the control plot. Thinning was completed during 1989 and the study was conducted during the 1889/90 (169 mm rain), 1990/91 (440 mm rain) and 1991/92 (214 mm rain) seasons (July - June). Above-ground dry matter (DM) yield of grasses within the 7 tree density plots was determined at the end of each growing season, normally April or May. All grasses were harvested in quadrats (0.25 m<sup>2</sup>), randomly placed in each experimental plot. Three subhabitats were distinguished: between tree canopies (uncanopied - UCA), under trees (canopied - CA) and where trees have been removed (removed canopy - RCA). A total of 60 quadrats per plot were harvested, 20 randomly allocated to each subhabitat (30 quadrats in the 0 % and 100 % plots where only 2 of the 3 defined subhabitats were represented). Rooted grasses within each quadrat were clipped to stubble height (0.1-3.0 cm) using hand clippers, dried to a constant mass (70°C) and weighed.

At the end of the growing seasons the leaf volume of the *C. mopane* trees was calculated using the BECVOL-model (Biomass Estimates from Canopy Volume) (Smit,

1989a, 1989b, 1994). This model incorporates a regression equation, which relates spatial canopy volume (independent variable) to leaf volume (dependent variable):  $\ln y = -3.196 + 0.728x$ ,  $r = 0.975$ ,  $P < 0.001$ . Spatial tree canopy volume ( $x$ ) was transformed to its normal logarithmic value, while  $y$  represents the leaf volume ( $\text{cm}^3$ ). The number of Evapotranspiration Tree Equivalents  $\text{ha}^{-1}$  was subsequently calculated from the leaf volume estimates (1 ETTE = mean leaf volume of a single-stemmed tree with a height of 1.5 m =  $500 \text{ cm}^3$  leaf volume) (Smit 1989a). The spatial canopy volume of each tree is calculated from measurements taken of the tree canopy. Relations between tree leaf volume and the DM yield of grasses were established using regression analyses (Draper & Smith 1981).

## **Results and Discussion**

The grass DM yields were generally low during the first, low rainfall season (1989/90), but substantially higher in the following seasons. The yields between tree canopies (UCA) (Figure 1a) were of the same order than under tree canopies (CA) (Figure 1b), with the yields where trees have been removed (RCA) initially the highest (Figure 1c). The seasonal grass yield patterns largely followed the rainfall pattern, but the yields of the UCA-subhabitat continued to improve during the third season (1991/92) with less than half the rainfall of the previous season (1990/91). After the third season this subhabitat yielded grass DM of the same order than that of the RCA-subhabitat with the lowest yields under tree canopies (CA).

Relations between tree leaf biomass, expressed as Evapotranspiration Tree Equivalents (ETTE)  $\text{ha}^{-1}$ , and grass DM yield were established independently for each of the three seasons and for each of the defined subhabitats (Table 1). Negative relationships between ETTE  $\text{ha}^{-1}$  and total grass DM yield were established, but this relationship became more pronounced with

each consecutive season. Total grass DM yield (all subhabitats combined) changed from a non-significant ( $P>0.05$ ) linear relationship during the first (dry) season (1989/90) (Table 1) to a significant curvilinear ( $P<0.05$ ) relationship during the second and third seasons. The best fit to these curvilinear relations was achieved by the exponential regression equation. The gradient of the curve was steeper in the 1991/92 relation, indicating an increasing difference between grass DM yields of the totally cleared plot (0 %) and the rest of the treatments. Examination of the grass DM yields within the respective *C. mopane*-subhabitats revealed trends similar to that already presented for the combined *C. mopane*-habitat. Significant negative relationships between grass yield and ETTE ha<sup>-1</sup> were particularly eminent after the second (1990/91) and third (1991/92) seasons within the UCA and RCA-subhabitats. This negative relationship was less strongly defined in the CA-subhabitat (Table 1). The negative curvilinear relationships correspond to those described for some other savanna veld types (Dye & Spear 1982). This relationship implies that the highest grass DM yield is obtained where all the *C. mopane* trees are removed. Since grass yields under tree canopies were lower than between tree canopies, and the high yields where trees were removed are likely only temporary, it would appear that no advantageous grass-tree interactions, evident in several other savanna veld types (Smit & Swart 1994), exist in the Mopani savanna. Thinning of *C. mopane* with the exclusive objective of increasing productivity of the grass layer would invariably involve a compromise situation where some trees should be left for the sake of possible qualitative benefits on the herbaceous layer (species differences), as well as other considerations like browse production, soil enrichment and esthetical considerations.

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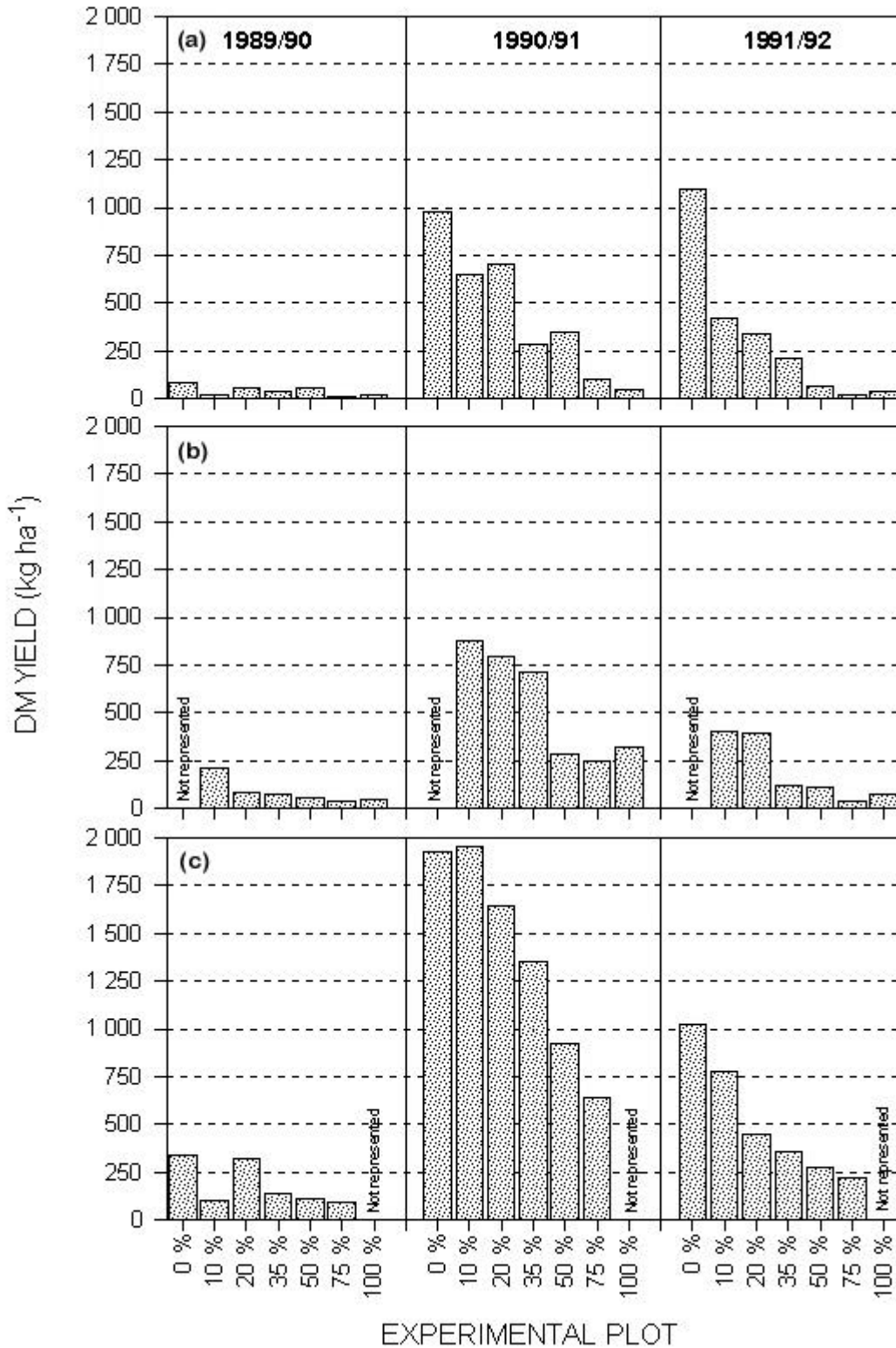
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**Table 1** - Results of the regression analyses of the relationship between the total grass DM yield of grasses within the combined *Colophospermum mopane*-habitat and each of the defined subhabitats (dependent variable) and Evapotranspiration Tree Equivalents (ETTE) ha<sup>-1</sup> (independent variable).

Subhabitat	Season	Regression equation	r <sup>2</sup>	r	n	P
Subhabitats combined	1989/90	$y = 73.424 - 0.0104x$	0.370	-0.608	7	0.209 ns
	1990/91	$\ln y = 7.039 - 0.000440x$	0.870	-0.933	7	0.003 **
	1991/92	$\ln y = 6.709 - 0.000551x$	0.841	-0.917	7	0.004 **
Between trees (UCA)	1989/90	$y = 57.188 - 0.00765x$	0.282	-0.532	7	0.220 ns
	1990/91	$\ln y = 7.017 - 0.000510x$	0.861	-0.928	7	0.003 **
	1991/92	$\ln y = 6.708 - 0.000579x$	0.828	-0.910	7	0.004 **
Under trees (CA)	1989/90	$\ln y = 5.052 - 0.000274x$	0.679	-0.824	7	0.044 *
	1990/91	$\ln y = 6.936 - 0.000257x$	0.662	-0.814	7	0.049 *
	1991/92	$\ln y = 6.099 - 0.000349x$	0.567	-0.753	7	0.084 ns
Trees removed (RCA)	1989/90	$y = 274.648 - 0.0479x$	0.358	-0.599	7	0.209 ns
	1990/91	$\ln y = 7.745 - 0.000284x$	0.868	-0.932	7	0.007 **
	1991/92	$\ln y = 6.936 - 0.000466x$	0.980	-0.990	7	0.002 **

(ns = not significant, \* = significant P<0.05, \*\* = significant P<0.01)





**Figure 1** – Total seasonal dry matter yields of grasses within the defined subhabitats of the larger *Colophospermum mopane*-habitat: (a) between tree canopies (UC=uncanopied), (b) under trees (CA=canopied), and (c) where trees have been removed (RCA=removed canopy).

