Influence of Shading Intensity on Herbaceous Vegetation Production under Trees of *Eucalyptus camaldulensis*, Dehn.

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ABSTRACT

Production of understory vegetation was studied under different shading intensities of mature to overmature *Eucalyptus camaldulensis* Dehn. trees, and compared to that of an adjacent open rangeland. Canopy coverage was measured directly through the multiplication of tree density, by tree crown area. The latter being a resultant of tree crown diameter measurements.

Results showed that canopy coverage gave a more accurate estimation of shading intensity than either of its two components: tree crown diameter, and tree density. Total vegetation production decreased ($P < 0.01$) as a result of increased shading. Yields of grasses and shrubs were equally depressed under tree canopies compared to open range. However, the proportion of grasses over total vegetation was more adversely affected by higher shading intensities than that of shrubs, which remained fairly constant. In the open range, grasses made up 77.0% of the total herbaceous production. They also outyielded shrubs at all shading levels, except the highest one. Such uncommon grass predominance in Libyan rangelands was attributed to beneficial long-term protection of the study area from grazing.

Forbs responded quadratically to canopy coverage, and its parameters, while other herbage categories declined linearly. Tree crown diameter was found to be the best independent variable in linear yield prediction for grasses, shrubs, and total herbage. It was followed by canopy coverage, and then density. However, the latter parameter was strongly correlated ($R^2 = 0.884$) with the yield of forbs in a quadratic regression model. In this study, forbs were mostly represented by *Plantago amplexicaulis* Cav., which may therefore, require a particular forest microenvironment provided by moderate forest shading.

INTRODUCTION

Understory forage production was shown to decline under various forest tree species such as acacias (3), eucalyptus (19), junipers (17), pines (6), and oaks (9). It was also reported that an increase in both tree size and density caused a concomitant decrease in herbage yield of forbs, shrubs, and grasses growing beneath trees (16). This decline in understory species production could be attributed to other factors, such as root competition for soil moisture (12), shading (17), litter accumulation (10), and

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allelopathy (14). Additionally, tree canopies were found to intercept significant amounts of rain, resulting in relatively drier conditions for the understory vegetation (13).

Conversely, greater understory herbaceous production compared to that in open stands was reported by several other workers (6, 9, 10). This increase was related to more favorable chemical and physical conditions under the trees than in open stands (2). Moreover, moderated soil temperatures and lower evapotranspiration moisture loss under tree canopies, may improve growth and herbage yields of understory vegetation (9), especially during drought (6).

Nevertheless, percent canopy coverage, which is a reflection of shading intensity, was suggested to be the most important factor influencing herbage production under forest trees (17). However, its indirect measurement, by simple ocular estimation or through densiometer readings, lacked accuracy and precision (17). Likewise, other canopy characteristics that did not provide a realistic evaluation of shading, used by earlier researchers, were unsatisfactory. These included tree basal area (11, 19), density (3, 16), canopy closure (10, 11), and trunk size (9, 17).

Overstory-understory relationships, largely mediated through shading intensity, affect the utility and the purpose of grazing. In rangelands, tree invasion may be controlled biologically by grazing the proper kind of livestock (4). In forests and afforted lands, grazing could be an efficient silvicultural tool in reducing the costs of both thinning (19), and eliminating competing vegetation from planted stands during establishment (4, 8). Furthermore, the economic returns from grazing North African forest lands were estimated to be 2 to 5 fold higher than those obtained from woody products (15). In Libya, ambitious afforestation programs have been planned and executed during the last few decades. For instance, more than 150,000 hectares were planted with various tree species in only five years, from 1976 to 1980 (1). it is, therefore, imperative that the afforested lands fulfil their role in providing forage for both wild and domesticated grazers. Hence, an understanding of the overstory-understory relationships in these plantations, is necessary for a better evaluation and prediction of their grazing potential. The purpose of this study was to investigate the effects of shading intensity on herbage production of the understory vegetation, in a planted stand of *Eucalyptus camaldulensis* Dehn., in western Libya, using direct measurements of canopy coverage.

MATERIALS AND METHODS

The study was conducted in a pure eucalypt stand juxtaposing an open rangeland. The study site is located at the Agricultural Research and Experimentation Station, College of Agriculture, Tripoli. The area is characterized by a semiarid climate, with a mean annual rainfall of approximately 335mm (1). About 94% of the total precipitation falls during the growing season, from October to April. Mean maximum monthly temperatures for January and August are 17.2 and 31.6° C, respectively. Mean minimum monthly temperatures for January and August are 8.1 and 21.8° C (1). The soil is a Typic Torripsamment, with a gently rolling relief and intermittent drainages. Mature to overmature eucalypt trees were the sole overstory dominants. They were planted in 1973. Since then, the area had been almost completely protected from grazing. Vegetation beneath trees and in the adjacent open range was quite similar. It is mainly comprised of *Artemisia campestris* L., *Cynodon dactylon* (L.) Pers., *Oryzopsis miliaceae* (L.) Asch. & Schw., *Plantago amplexicaulis* Cav., *Rhantherium suaevelens* Desf., and numerous other minor species.

Experimental units consisted of 25 plots of 40 × 25m. They were selected randomly, except for the requirement that they be of different shading intensities. Five of these plots were delineated in the adjacent open range. They represented replicates of the no shading treatment (0% canopy coverage). The remaining 20 plots were delimited in the afforested land, and were classified into 4 other shading intensities (I to IV), on the basis of their approximate similarity in the percentage of tree crown cover. Thus, each of the 5 treatments or shading intensities included 5 plots or replicates. Within experimental units, percent canopy coverage was measured directly, by multiplying the number of trees that were present, by the average tree crown projection area on the plot ground. Average projected crown area was calculated from the mean crown diameter of 5 randomly selected trees in each plot. Before that, crown diameter projections of the selected trees were measured on the ground from different directions using a 6m high wooden pole, that was held at the edge of the crown, and parallel to the tree trunk. Within each plot, herbaceous vegetation was sampled by 30 random frames of 0.30 × 0.61m dimensions. Current year's aboveground production was clipped by a pair of mechanical shears. Harvested herbage was sorted into grasses, forbs, and shrubs. It was separately stored in properly labelled paper sacks. Samples of each plot were composited by herbage category, air dried during 4 weeks, and then weighed. All field measurements were made in late April, at the end of the 1992/93 growing season.

Analysis of variance was used to test for differences among levels of canopy coverage, tree crown diameter, and tree density. A protected Fisher's least significant difference (LSD) was used to compare means of different shading intensities (18). The same procedures was followed for the comparison of mean production of grasses, forbs, shrubs, and total herbaceous vegetation. A multiple regression analysis was undertaken using each herbage category as the dependent variable, and canopy coverage, crown diameter, and tree density as independent variables (5). Significance in analysis of variance and regression was declared at the 0.01 and 0.05 probability criterion levels.

RESULTS AND DISCUSSION

There were significant differences ($P < 0.01$) among all shading intensities for measurements of canopy coverage (Table 1). This meant a relative homogeneity in tree foliage denseness of plots allotted to similar shading levels. Higher canopy coverages were caused, to a large extent, by greater tree crown diameters, although no significant differences ($P > 0.05$) were noticed between shading intensities I and II, as well as II and III, in projected crown diameters (Table 1). Tree density, the second component of canopy coverage, increased significantly ($P < 0.05$) between 0 and approximately 50% canopy coverage (Table 1). However, no significant differences in this parameter were noticed at higher shading intensities. Moreover, there was little difference in tree density between 24.40 and 79.36% canopy coverage. This suggested that greater canopy coverages were mostly caused by larger crown areas than by higher densities. Consequently, differences in shading intensities were better detected by direct measurements of canopy coverage, than by either tree crown diameter, or tree density alone.

Table 1 – Multiple comparisons of the means of the five shading intensities using Fisher's LSD for canopy coverage, tree crown diameter, and tree density.

Shading intensity	Canopy coverage (%)	Tree crown diameter (m)	Tree density (n/ha)
0	0.00 E[1]	0.00 D	0.00 C
I	24.40 D	4.97 C	126.00 B
II	50.16 C	5.86 BC	194.00 A
III	63.36 B	6.82 B	176.00 A
IV	79.36 A	8.35 A	148.00 AB
LSD	5.41**	1.10**	48.02*

[1]Similar letters denote no significant differences between means of each column. (*: $P<0.05$, **: $P<0.01$).

A highly significant ($P<0.01$) decreasing trend in herbage yield of total understory vegetation was recorded for increased shading intensities (Table 2). Highest total herbage production was obtained from the adjacent open range, where there was no tree canopy effect. By contrast, lowest yields resulted from plots of the two highest shading intensities III and IV. Nevertheless, no significant ($P>0.05$) differences in total vegetation production were recorded among plots of intermediate shading intensities (Table 2). This was due to the similarity of these plots in either tree crown diameter, and/or tree density (Table 1). Concording results showing lowered understory vegetation production under increased shading intensity of eucalypt trees was previously reported (20).

Table 2 – Production of grasses, forbs, shrubs, and total herbaceous vegetation, as affected by different tree shading intensities.

Shading intensity	Herbage production (kg/ha air dry)			
	Grasses	Forbs	Shrubs	Total
0	895.6 A[1]	20.5 C	246.5 A	1162.5 A
I	229.3 B	199.1 A	118.4 B	546.8 B
II	156.1 B	241.1 A	111.9 B	509.1 B
III	139.9 B	113.0 B	68.9 B	321.8 BC
IV	17.2 B	111.9 B	35.5 B	164.7 C
LSD	262.4**	79.3*	96.1**	257.2**

[1]Similar letters denote no significant differences between means of each column (*: $P<0.05$, **: $P<0.01$).

Yields of grasses and shrubs were equally depressed at all shading levels compared to those obtained under open range (Table 2). However, grasses and shrubs responded differently to higher shading intensity, than it may seem. The contribution of shrubs to the total herbaceous production remained fairly constant at all shading intensities. It ranged from a low of 21.2% in the open range, to a high of 22.0% at shading level II (Table 2). Whereas, a significant ($P<0.05$) declining trend in the proportion of grasses was found, as a result of increased canopy coverage. In the adjacent open range, grasses made up 77.0% of the total herbage yield (Table 2). This proportion was significantly ($P<0.05$) lowered to 41.9%, and 10.4% at shading intensities I, and IV respectively ($LSD_{0.05} = 18.2$). At shading levels II and III, grass yields amounted to 30.7% and 43.5% of all herbaceous production. These yields were not however, significantly different from each other, or from that of shading intensity I. The constancy of shrub proportions, combined with the declining trend of those of grasses, suggested that the latter were more severely affected by higher shading than were woody species. This inference could not have been made by relying on actual herbage production weights shown in table 2. Such a greater adverse effect of shading on grasses compared to shrubs, was previously demonstrated (16). It is further corroborated by lower slopes in all grass yield prediction models, compared to those of woody species (Table 3).

Table 3 – Regression models for production of grasses, forbs, shrubs, and total herbaceous vegetation, using canopy coverage, tree crown diameter, and tree density as independent variables.

Herbage production (kg/ha)	Canopy coverage (%)	Tree crown diameter (m)	Tree density (n/ha)
		Linear models ($Y = a + bX$)	
Grasses	$Y = 708.35–9.68X$ $R^2 = 0.660^{**}$	$Y = 833.44–104.97X$ $R^2 = 0.803^{**}$	$Y = 763.53–3.70X$ $R^2 = 0.630^{**}$
Forbs	–[1]	$Y = 66.58–13.56X$ $R^2 = 0.174^{*}$	$Y = 39.12–0.76X$ $R^2 = 0.346^{**}$
Shrubs	$Y = 219.85–2.38X$ $R^2 = 0.615^{**}$	$Y = 244.50–24.66X$ $R^2 = 0.681^{**}$	$Y = 216.45–0.78X$ $R^2 = 0.428^{**}$
Total	$Y = 1029.15–11.23X$ $R^2 = 0.770^{**}$	$Y = 1144.52–116.08X$ $R^2 = 0.851^{**}$	$Y = 1019.10–3.71X$ $R^2 = 0.550^{**}$
		Quadratic models ($Y = a + bX + cX^2$)	
Forbs	$Y = 31.39 + 8.48X$ $-0.10X^2$ $R^2 = 0.120^{**}$	$Y = 24.09 + 66.68X$ $-6.61X^2$ $R^2 = 0.377^{**}$	$Y = 664.1 + 4356.65$ $X - 507.03X^2$ $R^2 = 0.884^{**}$

[1]Model not included because of nonsignificance ($P>0.05$).

*: $P<0.05$; **: $P<0.01$.

Nonetheless, grasses outyielded shrubs in the open range, as well as under all tree shading intensities, except the highest one. In recent history of Libyan rangelands, dominance of grasses was rarely reported, as common overuse lead to the predominance of shrubs (7). However, long-term protection of the study site from grazing, improved tremendously the botanical composition by enhancing the growth of grasses, especially in the open range, where they made up 77.0% of the total herbage yield. This finding demonstrated the benefits from longterm protection, often recommended for severely misused rangelands (15).

Forbs were differently affected by increased shading compared to other herbage categories. Their highest production was obtained at shading levels I and II, while lowest yields occurred at shading intensities 0, III and IV (Table 2). This suggested a quadratic pattern of response to shading. Further support to this hypothesis was provided by regression analyses (Table 3). Indeed, all linear models using forb production as a dependent variable, and canopy coverage, or any one of its two components (tree crown diameter, and density) as independent variables, were either not significant ($P > 0.05$), or had relatively low R^2 values (Table 3). However, quadratic regression largely improved the prediction of forb yields, due to their higher significance ($P < 0.01$), and/or greater R^2 values (Table 3). A similar response pattern as that of forbs was found for various understory plant species (6, 9, 17). Forbs were essentially represented by *Plantago ampexicaulis*. It was concluded that this species may require a particular forest microenvironment of lower temperature, and lower light intensity compared to open range. This explanation fitted well with the significant ($P < 0.05$) depression of forb production at the highest 2 shading levels (Table 2). Indeed, larger crown diameters of mature and overmature trees were found to admit more light due to greater branch spreadout (17).

By contrast, all linear yield predictions of grasses, shrubs, and total herbaceous vegetation were significant ($P < 0.01$), and had negative slopes (Table 3). Similar results were reported elsewhere for the same herbage classes (16, 17, 19). However, tree crown diameter was the best predictor of all tested independent variables. Its models resulted in the highest R^2 values, followed respectively by those of canopy coverage, and tree density (Table 3). These findings agreed with multiple regression results of (17), which showed that tree crown diameter and canopy coverage were the most consistent predictors among several other canopy characteristics affecting growth of herbaceous species. In that study, crown diameter recurred in 11 models, while canopy coverage occurred in only 8, out of a total of 22 models of multiple variable regression (17).

Consequently, measurement of only tree crown diameter is sufficient for providing reliable prediction of the grazing potential under mature to overmature forest canopies. Moreover, accurate estimation of shading intensity can only be achieved through direct, but tedious, measurements of canopy coverage, since easier indirect methods using densiometers, or ocular estimates were reported to lack accuracy, and sometimes, feasibility (17). Estimation of tree density alone, was necessary for predicting forb production, due to the strong quadratic correlation ($R^2 = 0.884$) between these 2 variables (Table 3). Using density as the sole [parameter for estimating canopy coverage, or predicting total herbaceous production may no longer be justified, although it had been used as such in earlier research work (3, 16). Further investigations are needed to assess the influence of younger tree stands or understory species production. Indeed, tree canopy characteristics change with age, and so does their grazing potential.

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تأثير شدة الظل على إنتاجية النبات العشبي تحت أشجار الأوكالبتوس (Eucalyptus camaldulensis Dehn.)

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المستخلص

تمت دراسة إنتاجية النباتات النامية تحت مستويات مختلفة من ظل أشجار الأوكالبتوس (Eucalyptus camaldulensis Dehn.) بلغت النضج أو تجاوزته، وتمت مقارنتها مع إنتاجية هذه النباتات في مرعى مفتوح مجاور. جرى قياس نسبة الظلة الشجرية مباشرة بضرب كثافة الأشجار في مسادة التاج، الناتجة عن قياسات قطر التاج.

أبرزت النتائج أن الظلة الشجرية قدرت تأثير شدة الظل بأكثر واقعية من عنصريها الاثنين: قطر تاج الشجرة وكثافة الأشجار. لوحظ انخفاض معنوي ($P<0.01$) في الإنتاجية الكلية للنباتات كنتيجة لتزايد شدة الظل. كما قل محصول النجيليات والشجيرات تحت تيجان الأشجار مقارنة بمحصولها في المرعى المفتوح. لكن، نسبة النجيليات إلى النباتات الكلية تأثرت سلبياً بتزايد الظل أكثر من الشجيرات التي بقيت نسبها ثابتة تقريباً. شكلت النجيليات في المرعى المفتوح حوالي 77.0٪ من الإنتاج العشبي الكلي، وتجاوزت محصول الشجيرات عند كل

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مستويات الظل، ما عدا أشدها. تعود سيادة النجيليات هذه، غير المعهودة في المراعي الليبية، إلى فوائد حماية موقع الدراسة من الرعي لفترة طويلة من الزمن.

استجابت المستعرضات للظلة الشجرية ولعناصرها بنمط تربيعي، بينما انخفضت إنتاجية المجموعات العشبية الأخرى خطياً. وجد أن قطر تاج الشجرة كان أحسن متغير مستقل، تليه الظلة الشجرية ثم الكثافة، في التنبؤ خطياً بإنتاج النجيليات والشجيرات ومجموع الأنواع العشبية. كما ثبت وجود علاقة قوية بين كثافة الأشجار وإنتاجية المستعرضات، والتي برزت في نموذج ارتداد تربيعي. إن النباتات المستعرضة، والمتمثلة خاصة في .Plantago amplexicaulis Cav، قد تتطلب وسطاً بيئياً دقيقاً توفره ظلة غابوية معتدلة.

شكر

يتقدم البحاثون إلى قسم المراعي والغابات، ومحطة التجارب والبحوث الزراعية، وكلية الزراعة بطرابلس، بعبارات الشكر لدعمهم المادي لهذا البحث.