Growth, Aboveground Dry Matter Production and Allocation of Young *Acacia salicina* Trees under Early Thinning

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ABSTRACT

Three early thinning operations were sequentially applied to *Acacia salicina* trees planted in intensive culture from they were 16 months old. The experiment was carried out at the Research and Experiments Station of College of Agriculture, King Saud University, Riyadh, Saudi Arabia. 330 seedlings of four months old were planted in the field in October1998. They were planted at 1.25 x 1.25 m spacing using a randomized complete block design comprises three blocks with starting density of 6400 tree h^{-1}. Thinning operations were done in February of the years 2000, 2001 and 2002. Results indicated significant increases in stem height and diameter of the trees as well as total dray matter production and its components after the third thinning. The thinned plots produced 6.264, 18.672, 15.864 and 40.800 ton h^{-1} for leaves, branches, stem and total aboveground dry matter comparing with 1.472, 2.232, 4.584 and 8.288 ton h^{-1} for the same components in unthinned plots, respectively. The proportion of dry matter allocated to branches increased due to thinning mainly at the expense of stem weight ratio whereas leaf fraction did not change significantly.

Key words: *Acacia salicina*, thinning, growth, dry matter production and allocation

INTRODUCTION

Biomss is a measure of biological matter usually expressed in weight. Tree biomass may be that of a single individual or all individuals occupying unit of area. Biomass energy begins to play a significant role in the global energy supply. Estimating tree biomass is an important way to measure the energy potential of a forest (Grubb *et al.* 2001). Moreover, as trees develop a large biomass, they capturing large amounts of carbon over a growth cycle of many decades. Thus, a forest ecosystem can capture and retain large volumes of carbon over long periods. Thus, forests operate both as vehicles for capturing additional carbon and as carbon reservoirs (Sedjo 2001). Estimating biomass, therefore, is the main tool by which the share of trees in carbon sequestration can be calculated.

Producing biomass through short-rotation forestry has been practiced for energy and the sustainability of this practice is dependent upon such factors as biomass yield biomass potential, tolerance of poor habit, climatic condition, and biomass fuel value (Neenan, 1980). *A. salicina* is regarded as one of the most important of the introduced Australian acacias that have been introduced into Africa and the Near East on account of its tolerance to moderate drought, ability to grow on poor soil and bind sand, high biomass production, high nutritive value for sheep and goats, ease of establishment and management and response to irrigation (El-Lakany 1987). However, maximizing significant gain of planting such species requires suitable management compatible with the purpose desired. Successful tree plantation is that allow all individuals to get sufficient light, water and nutrients for performing the proper growth. This because crowded trees will eventually compete with each other for light, soil moisture and soil nutrients. The theme of thinning therefore, is removing some of the trees that compete for limited below-ground resources makes more water and nutrients available for the remaining trees. In addition, thinning opens the crown canopy of the tree plantation making more light available for the remaining trees. In the present study, growth, aboveground biomass production and allocation of *Acacia salicina* trees under early thinning were examined.

MATERIALS AND METHODS

Site description

The site where the experiment was carried out has the following characters: 24° 6' N, latitude; 46° 5' E, longitude, 650 m altitude; temperature ranged between 10°C in winter and 37°C in summer (as an average of season); and 50 mm rainfall, annually. The soil of the site was sandy loam with average content of 61, 23 and 15% for sand, silt and clay, respectively (Aref 1987).

Planting technique and statistical design

330 seedlings of four months old *Acacia salicina* (Lindley) were planted in the field in October1998. They were planted in 15 rows, with 22 trees in each row. The space between and within rows was 1.25 × 1.25 m. The total planted area was 463.75 m^2 (26.5 m long × 17.5 m wide), with a starting density of 6400 trees $hectare^{-1}$. The trees were irrigated once a week in winter and every four days in summer throughout the course of the experiment. The planted area was divided into three blocks with two experimental plots each using a randomized complete block design.

Thinning operations and Measurements

In February 2000, three plots were chosen randomly and subjected to mechanical thinning, where each other diagonal tree line was removed. Thereafter, these plots were thinned twice in February 2001 and February 2002. The first two thinning operations reduced the number of tree from 6400 to 1600 tree $hectare^{-1}$ in the thinned plots while the third one reduced it to 800 tree $hectare^{-1}$. The other three plots were kept without thinning up to the end of the experiment.

By the end of the experiment, stem height, diameter and total leaf area of the trees in both thinned and unthinned plots were measured. Stem height was measured from the soil surface to the top of tree while stem diameter was measured at a previously marked point at 10 cm on the bole above soil surface. Leaf area of the trees was scaled within few hours from the time of harvesting using a leaf area scanner (Hayshai Denkoh Co., LTD, Tokyo, Japan).

In February 2003, nine trees were randomly chosen and taken as representative sample from unthinned plots as well as other nine from the thinned plots. These trees were felled and separated into stem, branches and leaves. Samples of leaves were oven dried at 70 °C for 24 h, while those of stem and branches were dried at 102°C±3. Total tree aboveground dry weight for each tree were calculated as well as dry matter allocation to each component. Aboveground dry matter per hectare for both thinned and unthinned plots was estimated.

Leaf, Branch and stem weight ratio (LWR, BWR and SWR) were calculated as a proportion of total dry weight and by dividing the dry weight of each on total dry weight. Relative growth rate (RGR) was calculated using the covenantal equation (Hunt 1978) as the following: $RGR = (Log_e W_2 - Log_e W_1) / t_2\text{-}t_1$

Where: W_1 and W_2 are total dry weights of the trees at the beginning (t_1) and the end of the experiment (t_2).

Statistical analysis

Analysis of variance procedure was used to analyze the obtained data through SAS computer program (SAS Institute 1987). The means of treatments for different variables were compared using L. S. D. test (Steel and Torrie 1981).

RESULTS

Early thinning caused significant effects on the growth, dry matter production and allocation of *Acacia salicina* trees. The thinned trees had significantly greater stem height ($P<0.05$), diameter ($P<0.0001$) and total leaf area ($P=0.003$) in comparison with those in unthinned plots. The increases in these traits were 20, 95 and 300%, respectively (Table 1). Leaf, branches, stem and consequently total dry matter of the thinned trees also increased by 325, 736, 246 and 392%, respectively comparing with unthinned trees (Figure 1). Mean relative growth rate (RGR) of the thinned trees accounted for 0.725 kg kg^{-1} $year^{-1}$ compared with 0.559 kg kg^{-1} $year^{-1}$ for the unthinned trees (Table 1). Estimating dry matter production per hectare showed that under thinning *Acacia salicina* trees at age about 4.5 years produced leaf, branches, stem and total dry matter accounted for 6.264, 18.672, 15.864 and 40.800 ton ha^{-1} while unthinned trees produced 1.472, 2.232, 4.584 and 8.288 ton ha^{-1}, respectively (Table 2).

Allocation of aboveground dry matter changed due to thinning where stem weight ratio increased mainly at the expense of branch weight ratio as leaf weight ratio was unaffected (Figure 2).

DISCUSSION

The principle of thinning out is to encourage the development of certain trees considered to be valuable, usually for economic purposes, by eliminating neighbouring ones. This technique can only be used in closed stands. The investment in terms of time and manpower guarantees a reasonable economic return in terms of the quality and quantity of the volumes harvested. In the present work, stem diameter and height of *Acacia salicina* trees increased by 95 and 20% due to thinning. Increasing stem diameter of forest trees under thinning was reported by many researchers (e. g. Hibbs *et al.* 1989; Burns *et al* 1996; Peterson *et al.* 1997; Zhang *et al* 1997; Ansley *et al.* 1998; Graham 1998 and others). However, Bartelink (1998) asserted that stem diameter growth of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and beech (*Fagus sylvatica* L.) appeared relatively constant in response to thinning. Effects of thinning upon height growth on the other hand is debatable, where some researchers found it increased and others reported no effect or even decrease. The increased stem height in the present study agrees with the results reported for forest trees by Burns *et al.* (1996); Zhang *et al.* (1997) and Ansley *et al.* (1998). Contradictory, Hibbs *et al.* (1989) found stem height of red alder trees decreased under thinning while Graham (1998) reported unaffected tree height. These results may be interpreted in the light of Jonstone's statement (1985) that wide spacing may induce extremely rapid crown expansion so that diameter growth accelerates at the expense of height growth. The intensity of the thinning and the time since thinning, along with the inherent site quality, will determine the magnitude and duration of the thinning response (Zhang 1998).

Increasing dry matter production due to thinning in the present study concurs with the finding of Cissé and Koné (1992) with *Faidherbia albida* (*Acacia albida*); Mrling (1999) with Scots pine; Sudhir *et al.* (1983) and Mishra *et al.* (1986) with *Leucaena leucocephala* and Kushalapa (1987) with *Casuarina equestifolia*. These results are a consequence of the ability of the remained trees (after thinning) to invest below-round resources and to the accessibility of their live branches to have more light, and hence continue to grow. However, this ability depends on some factors such as site quality and the age of trees (stand). Aref *et al.* (1999) mentioned that decreasing biomass production per tree in high-density plots is not surprising because most of the trees in such plantation if not all had small diameters and were shorter in height. Nevertheless, there are some results showed dry matter production of trees not affected and others reported decreases under thinning. West and Osler (1995) reported unaffected dry matter production of *Eucalyptus regnans* in one site, and other was substantially less than that in the unthinned stand in another site. Oliver and Larson (1990) and McWilliams and Therein (1996) elucidated this discrepancy in dry matter production of trees under thinning as they attributed the capacity of the remaining trees to take advantage of the decreased competition to the size, vigour, and distribution of their crowns. These factors, in turn depend on the site quality, the stand history, and stage of development.

Increasing relative growth rate of the trees in thinned plot in the present study concurs with the finding of Sheriff (1996) who attributed the increase in the growth rate of remaining trees after thinning to an increase in the availability of resources per tree. The estimated total aboveground dry matter for *Acacia salicina* trees in the thinned plots (40.0 ton ha^{-1}) considers almost similar to that of four years old *Acacia amplecips* (39.7 ton ha^{-1}) grown on 3 × 3 m spacing in a nearby location (Aref *et al.* 2003). This may a result of being both species of the phyllodineous acacia.

Increasing dry matter allocated to branches of the thinning at the expense of that allocated to stem accords with the result obtained by Aref *et al.* (1999). It also concurs, at least partly, with the conclusion of Bartelink (1998) that the most obvious response to thinning of Douglas-fir and beech stands consisted in a sharp decrease in partitioning to fine roots and foliage, and an increased investment in branches. In contrast, Beets and Whitehead (1996) reported no significant effect of thinning on dry matter partitioning *Pinus radiata* stands.

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Table 1. Stem height, diameter, total leaf area and relative growth rate of about 4.5 years old *Acacia salicina* trees under early thinning operations from when they were at 16 month old comparing with unthinned trees.

Trait	Probability level	Treatment	
		Unthinned	Thinned
Stem height (m $tree^{-1}$)	$P<0.05$	*6.66 [b]	8.00 [a]
Stem diameter (cm $tree^{-1}$)	$P<0.0001$	6.89 [b]	13.42 [a]
Total leaf area (cm^2 $tree^{-1}$)	$P=0.003$	143738 [b]	574638 [a]
Relative growth rate (kg $kg^{-1}year^{-1}$)	0.0001	0.559 [b]	0.725 [a]

* Means followed by the same superscript letters in every two consecutive boxes are not statistically different according to L. S. D. test.

Table 2: Aboveground dry matter production per unit area (ton ha^{-1}) of about 4.5 years old *Acacia salicina* trees under early thinning comparing with unthinned trees.

Treatment	Aboveground dry matter production (ton ha^{-1})			
	leaves	Branches	Stem	Total
Unthinned	1.472	2.232	4.584	8.288
Thinned	6.264	18.672	15.864	40.800

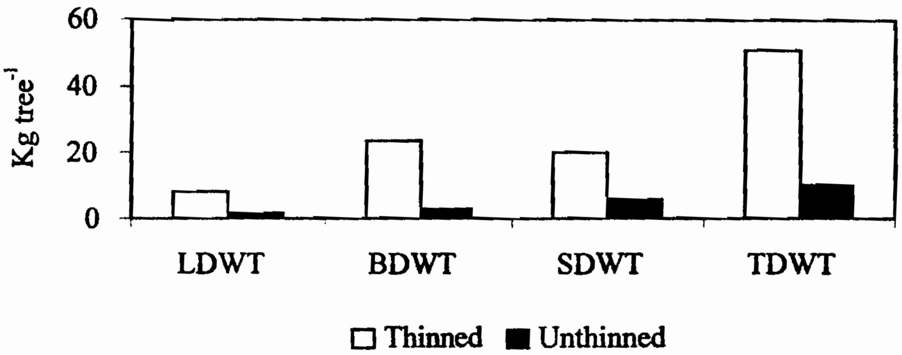

Figure 1. Leaf (LDWT), branches (BDWT), stem (SDWT) and total (TDWT) dry weight production (Kg tree^{-1}) of about 4.5 years old *Acacia salicina* in thinned and unthinned plots.

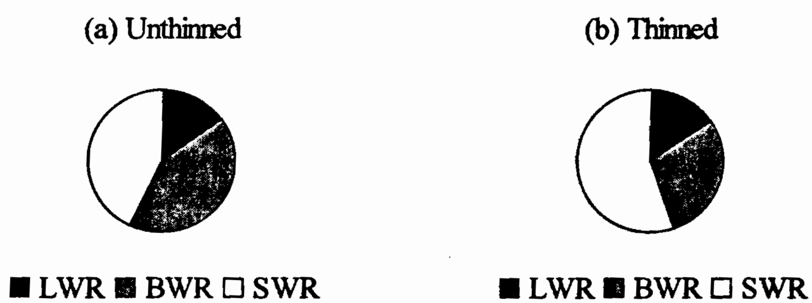

Figure 2. Allocation of aboveground dry matter of about 4.5 years old *Acacia salicina* trees into leaves, stem and branches in (a) unthinned and (b) thinned plots indicated by leaf (LWR), branches (BWR) and stem (SWR) weight ratio.

ملخّص عربي

نمو و إنتاج المادة الجافّة فوق سطح التربة و توزيعها في أشجار أكاسيا ساليسينا الصغيرة تحت الخف المبكّر

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ثلاث عمليات خف متتابعة أجريت على أشجار أكاسيا ساليسينا منزرعة في زراعة كثيفة ابتداءً من عمر ١٦ شهر. أجريت التجربة في محطّة الأبحاث و التجارب الزراعيّة التابعة لكليّة الزراعة بجامعة الملك سعود في الرياض بالمملكة العربيّة السعوديّة، حيث زرعت ٣٣٠ شتلة ذات عمر أربعة شهور في الحقل في أكتوبر ١٩٩٨. و قد زرعت الشتلات على مسافات ١,٢٥ × ١,٢٥ متراً باستخدام تصميم قطاعات عشوائية كاملة حيث زرعت ٦٤٠٠ شجرة في الهكتار في البداية. أجريت عمليات الخف في شهر فبراير من الأعوام ٢٠٠٠ و ٢٠٠١ و ٢٠٠٢ في ثلاث من القطع التجريبيّة الستة التي ضمتها التجربة بينما تركت القطع الثلاث الأخرى بدون خف. أوضحت النتائج وجود زيادة معنويّة بعد الخف الثالث في كلٍ من ارتفاع و قطر ساق الشجرة و كذلك في إنتاج المادة الجافّة الكليّة فوق سطح التربة و مكوناتها و في معدّل النمو النسبي. و قد أنتجت القطع التجريبيّة التي أجري خف الأشجار بها ٦,٣ و ١٨,٦ و ١٥,٩ و ٤٠,٨ طن للهكتار مادة جافّة للأوراق و الفروع و الساق و المادة الجافّة الكليّة فوق سطح التربة، على التوالي بالمقارنة مع١,٥ و٢,٢ و ٤,٦ و ٨,٣ طن للهكتار مادة جافّة لنفس أجزاء الشجرة، على التوالي في القطع التجريبيّة التي لم يجر بها خف. و قد ازدادت النسبة من المادة الجافّة الموزّعة إلى الفروع نتيجة للخف على حساب تلك الموزّعة إلى الساق كون نسبة المادة الجافّة الموزّعة إلى الأوراق لم تتغيّر معنوياً.