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Effect of Thinning on the above Ground Biomass of (*Conocarpus erectus* L.) Trees in the Western Region of Saudi Arabia

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Abstract. Benefiting from introduced exotic trees in Saudi Arabia is mostly limited to municipal uses. In order to establish forest plantations of those species, studies should be conducted concerning the effect of silvicultural practices on the plantations productivity. In the present study, we studied the effect of three thinning treatments, on 7 years old short rotation intensively cultured Buttonwood (*Conocarpus erectus* L.) plantation after 2 years of application. The thinning treatments were 0, 50 and 67% of stock. In exception of the increase in the dry matter (DM) of foliage, no significant influence of thinning was observed on the above ground dry matter (AGDM) of individual tree components. The average total above ground dry matter (TAGDM) ranged between 15.79 kg for unthinned to 22.44 kg for 67% treatment**.** In all treatments, stem wood accounted for the largest proportion of AGDM with the highest value for the unthinned (71.72 %), differing significantly from the other two treatments (62.88 and 63.05%). Of all tree dimension parameters, only crown diameter (CrD) and stand basal area (BA) were significantly influenced by the treatments. The 67% thinning treatment had the highest mean CrD **(**2.16 m), while the unthinned was the highest in BA (17.93 m^2 ha^{-1}). Several allometric equations were constructed relating DM of tree components and stem volume of individual trees with their diameter or diameter and total height. Except foliage DM all the relations were highly significant. The coefficients of determination (R^2) were 0.882, 0.899, 0.945, 0.996, 0.987 and 0.990 for twigs, branches, bark, stem wood, total **DM** and stem volume respectively.

Introduction

Interest in fast growing Short Rotation Intensively Cultured Trees (SRIC) has been growing as a source of small stem woody material for the industry and other purposes. This forest plantation system was designed to maximize fiber growth in woody plants (Geimer and Crist, 1980). Buttonwood is a mangle tree native to the North Caribbean Coast. It is widely spread in Saudi Arabia, mainly, as residential road side tree and in windbreaks especially in coastal regions. This tree possesses high tolerance of compacted and saline soil, air pollution, poor drainage, and drought (Gilman and Watson, 1993). Its wood has high calorific value as fuel and produces high-grade charcoal beside some other industrial and medicinal uses (Morton, 1981).

Several studies were carried out on Buttonwood in Saudi Arabia, but they were mostly restricted to small seedlings (Moftah and Al-Humaid, 2004, Al-Humaid and Moftah, 2007 and El-Juhany and Aref, 2005). On the contrary, very few studies were carried in this country concerning Buttonwood tree plantations (Al-Harbi, 2006).

Rytter (1995) stated that application of silvicultural operations in SRIC plantations may increase the value of the end harvested material. This value enhancement along with the intermediate cuttings may compensate for the cost of such practices. Thinning is known to influence growth and form of trees by reducing competition and by alteration of environment to be more suitable for the growth of remaining trees (Kramer and Kozlowski, 1979 and Daniel *et al.*, 1979). Piotto, *et al.* (2003) examined the growth and responses to thinning of native species in mixed and pure-species plantations in the Caribbean Lowlands of Costa Rica at 9-10 years of age. They reported that trees responded to thinning with increased diameter growth, while height was not generally influenced concluding that tight initial spacing and high stem extraction thinning can improve growth and timber quality. Muñoz, *et al.* (2008) investigated the effects of three thinning treatments, applied at age of 6 years, on the growth and aboveground biomass accumulation of a 15-year-old *Eucalyptus nitens* (Deane & Maiden) Maiden plantation. They found that the lowest stocking treatment doubled the average aboveground biomass of individual trees, but reduced stand mean aboveground productivity by 31% and increased average stem, crown, and total biomass. No differences in biomass and wood accumulation were found between 800 and 1100 trees ha^{-1} stockings. On the other hand, the 1100 trees ha^{-1} stocking, had a negative effect on live crown length.

In the mean time, many equations have been published relating tree biomass to diameter or diameter coupled with height (Hiratsuka *et al.*, 2004, Nordh and Verwijst, 2004, Cole and Ewel, 2006, Pilli *et al.*, 2006, Fehrmann and Kleinn, 2006, Peichl and Arain, 2007 and Sochacki, *et al.* 2007).

The objective of this study was to determine the effect of thinning intensity on the above ground biomass accumulation of intensively cultured *Concarpus erectus* L. The study aimed also to establish allometric equations for the prediction of different above ground biomass components.

Materials and Methods

Site Characteristics

The study took place in the experimental station of the Faculty of Meteorology, Environment and Arid Land Agriculture, King Abdulaziz University in Hada Al Sham. The site is located nearly 40 km North East of Macca (21° 48′ 3″ N, 39° 43′ 25″ E), at approximately 240 m.a.s.l. The soil in the location has very poor soil productivity, with soil pH ranging from 7.1 to 7.99. The organic matter, calcium carbonate and cations exchange capacity are low (Al-Solimani, 2003 and Al-Solimani, *et al.*, 2003). During the last decade, average monthly temperatures ranged between 23°C in January (winter) and 36°C in July (summer). Average annual rainfall was low and irregular at the site (100 mm app.). Mean relative humidity ranged between 57% (January) and 20% or less (June & July) with an average dry season of about 8 dry months during the year.

Field Work, Experimental Design and Data Collection

In spring 1999, the plantation was established in the location using transplants raised from stem cuttings in the nursery one year before. Spacing of planting was 1 m between trees and 1.75 m between rows (5700 tree ha^{-1}). Trees were drip irrigated using water from local wells on regular intervals.

The layout for the experiment comprised three blocks with three experimental units each. The blocks were situated adjacently in the middle of the plantation in order to avoid edge effects. Accordingly, the experimental design for this study was a randomized complete block design with three replicates (Steel and Torrie, 2000). Each replicate consisted of three experimental units of 30 trees in three rows of ten trees each. In spring 2005, three mechanical (systematic) thinning treatments, namely; without thinning, thinning of 50% of stock and thinning of 67% of stock were applied. The three treatments were randomly assigned to the plots in each replicate. A random sample of three standing trees was chosen from each plot for growth measurements and final above ground biomass (AGBM) assessment. In spring 2007, the chosen trees were felled down, divided into branches, twigs, stem and foliage components, and weighed fresh in field. Green samples were used for dry mass estimation of each tree component based on dry/green weight ratios. The diameter at breast height (DBH) and total plant height (H) of each tree were measured. Diameter measurements were conducted also on regular intervals of 40, 60 and 80% of H. The aforementioned measurements were used also for stem volume determination. The diameter and length of the crown of each sampled tree were measured as well. On the other hand, groups of leaf specimens from every sample tree were collected. The specific leaf area (SLA) for each group was determined by dividing its projected leaf area by its oven dry weight. Statistical analysis was done according to Steel and Torrie (2000) using SAS package V.8 (2000).

Results and Discussion

Above Ground Dry Matter of Individual Trees

Average DM of different above ground components on the individual tree level are presented in Table 1. In exception of foliage DM, values of above ground dry matter (AGDM) of the different tree components were not statistically different between thinning treatments. Stem wood DM ranged between 11.13kg tree^{-1} for the unthinned to 17.60 kg tree^{-1} for the 67 % thinning intensity but without any significant difference between treatments (Table 1). Bark DM ranged between 0.28kg tree^{-1} for unthinned and 0.59 kg tree^{-1} for the 67% treatment.

Table 1. Means of above ground dry matter (kg tree^{-1}) of various tree components as affected by three thinning treatments.

Thinning intensity (%)	Dry matter (kg tree^{-1})					
	stem		crown			Total dry matter
	Bark	wood	Twigs	Branches	Foliage	
0	0.28 ^{a*}	11.13 ^{a}	0.86 ^{a}	2.70 ^{a}	0.36 ^{b}	15.79 ^{a}
50	0.34 ^{a}	12.18 ^{a}	1.21 ^{a}	4.31 ^{a}	0.59 ^{b}	18.16 ^{a}
67	0.59 ^{a}	17.60 ^{a}	1.73 ^{a}	4.62 ^{a}	1.36 ^{a}	22.44 ^{a}

*Means followed by the same letter are not significantly different according to LSD at 0.05 level of probability.

Fewer DM was accumulated in the crown, mostly in branches, with an insignificant increase in DM of both twigs (0.86, 1.21 & 1.73 kg tree^{-1}) and branches (2.70, 4.31 & 4.62 kg tree^{-1}) with increasing thinning intensity from 0 to 50 then 67%. On the other hand, a significant increase in foliage DM was associated with the 67% treatment (1.36 kg tree^{-1}) compared to both unthinned (0.36 kg tree^{-1}) and the 50% treatment (0.59 kg tree^{-1}) which were not significantly different from each other. Consequently, no significant increase was observed between the mean values of TAGDM of different treatments ranging between 15.79 kg tree^{-1} for unthinned and 22.44 kg tree^{-1} for 67% treatment**.** These findings are in partial agreement with the findings of Muñoz, *et al.* (2008) in their work on *Ecalyptus nitens* (Deane & Maiden) plantation in Chile.

Aboveground Biomass

No significant differences in above ground biomass (AGBM) were observed between thinning treatments, but higher biomass values were observed at the unthinned treatment in most biomass components and TAGBM (Table 2). Similar results were encountered by Eriksson (2006) in his study in Sweden on young stands of *Pinus sylvestris* L. and *Picea abies* (L.) Karst. He stated that the unthinned treatment had the largest standing biomass for both species.

Again stem wood had the largest mean AGBM ranging between 63.60 t ha^{-1} for the unthinned and 33.53 t ha^{-1} for the 67 % thinning intensity. Bark mean AGBM was 1.58, 0.96 and 1.13 t ha^{-1} for the unthinned, 50% and 67% treatments, respectively. As for the crown, twigs AGBM ranged between 4.92 for unthinned and 3.29 t ha^{-1} for 67% treatment while, the mean AGBM of branches ranged between 15.43 for the unthinned and 8.80 for the 67% intensity. On the contrary, mean foliage AGBM increased insignificantly from unthinned (2.06 t ha^{-1}) to 67% treatment (2.59 t ha^{-1}). The total AGBM had the same insignificant trend with the mean values of 90.22, 51.88 and 42.74 t ha^{-1} for unthinned, 50% and 67% treatments respectively. Unthinned plots gave the largest (AGBM) mean values across treatments while, the lowest AGBM values were recorded for the 67% treatment (Table 2). However, no significant differences were found between treatments concerning AGBM of any tree component or TAGBM. Those values ranged between 0.96 to 01.58 t ha^{-1} for bark, 33.53 to 63.60 t ha^{-1} for stem wood, 3.29 to 4.92 t ha^{-1} for twigs, 8.80 to 15.43 t ha^{-1} for branches, 1.68 to 2.59 t ha^{-1} for foliage and 42.74 to 90.22 t ha^{-1} for TAGDM. Eriksson (2006) in his work on Norway spruce and Scots pine revealed ‘unthinned’ treatment had the largest standing biomass for both species, which resulted in that ‘unthinned’ is preferred if the objective is to maximize the standing biomass and thereby the carbon pool.

Table 2. Means of above ground biomass (t ha^{-1}) of various tree components as affected by three thinning treatments.

Thinning intensity (%)	Above ground biomass (t ha^{-1})					
	Stem		Crown			Total above ground
	Bark	wood	Twigs	Branches	Foliage	
0	1.58 ^{a*}	63.60 ^{a}	4.92 ^{a}	15.43 ^{a}	2.06 ^{a}	90.22 ^{a}
50	0.96 ^{a}	34.81 ^{a}	3.46 ^{a}	12.36 ^{a}	1.68 ^{a}	51.88 ^{a}
67	1.13 ^{a}	33.53 ^{a}	3.29 ^{a}	8.80 ^{a}	2.59 ^{a}	42.74 ^{a}

* Means followed by the same letter are not significantly different according to LSD at 0.05 level of probability.

Dry Matter Distribution

The effect of thinning treatments on the percentages of AGDM of individual tree components was also investigated. The analysis of variance was conducted after data transformation to achieve normal distribution of the data (Steel and Torrie, 2000). Stem wood DM accounted for the largest proportion of individual tree AGDM across treatments with the highest value for the unthinned (71.72 %), differing significantly from the other two treatments (62.88 and

63.05%) (Table 3). On the other hand, stem bark DM accounted for the lowest percentage of all components without any significant difference between treatments ranging between 1.89 and 2.12%. As for tree crown no differences in DM accumulation were found between treatments for twigs and branches. The latter had the highest percentage of the crown components in all treatments ranging from 16.72 to 22.55% of TAGDM, while twigs percentage ranged between 6.72 and 8.75%. The highest foliage percentage was recorded for the 67% thinning intensity (7.08%). This value was significantly different from the other two treatments. The mean foliage percentages of those treatments were 2.95 and 4.58 % for the 0 and 50% thinning treatments respectively.

Table 3. Effect of thinning on dry matter allocation.

Thinning intensity (%)	DBH (m)	Total height (m)	Stem volume (m^3 $tree^{-1}$)	Crown		Specific Leaf area (cm^2 g^{-1})	Basal area (m^2 ha^{-1})	Volume per unit area (m^3 ha^{-1})
				length (m)	Diameter (m)			
0	0.062*a	8.85 a	0.017 a	6.39 a	1.18 b	96.4 a	17.93 a	95.84 a
50	0.056a	7.46 a	0.017 a	5.53 a	1.53 b	92.5 a	8.40 b	47.76 a
67	0.073a	8.70 a	0.029 a	5.96 a	2.16 a	86.8 a	9.18 b	55.35 a

* Means followed by the same letter are not significantly different according to LSD at 0.05 level of probability.

The absence of any significant influence of the thinning treatments on most AGDM components in the present study, is not unexpected. This criterion can be attributed to the short period after which this study was conducted following the thinning treatments. Consequently, no sufficient dry matter was accumulated to show an obvious effect of thinning.

Tree Dimensions

Similarly most tree dimension parameters were not significantly affected by thinning treatments. Only, crown diameter (CrD) and stand basal area (BA), were significantly influenced by the treatments (Table 4). The 67% thinning treatment had the highest mean CrD (2.16m) differing significantly from the unthinned treatment (1.18 m) and the 50% thinning treatment (1.53m). The same trend was observed by Juodvalkis, *et al.* (2005) on 10–60 year-old stands of ash, aspen, birch, and oak, pine and spruce in Lithuania. Their results demonstrated that thinning enhanced crown projection area increment of residual trees.

Table 4. Mean values of individual tree dimensions as affected by three thinning treatments.

Thinning intensity (%)	Stem		Crown		
	Bark (%)	Wood (%)	Twigs (%)	Branches (%)	Foliage (%)
0	1.89 ^{a} *	71.72 ^{a}	6.72 ^{a}	16.72 ^{a}	2.95 ^{b}
50	2.12 ^{a}	62.88 ^{b}	7.86 ^{a}	22.55 ^{a}	4.58 ^{b}
67	2.08 ^{a}	63.05 ^{b}	8.75 ^{a}	19.05 ^{a}	7.08 ^{a}

* Means followed by the same letter are not significantly different according to LSD at 0.05 level of probability.

On the stand level, in our study, thinning resulted into a significant reduction of stand basal area (BA) from 17.93 m^2 ha^{-1} for unthinned to 8.40 and 9.18 m^2 ha^{-1} for 50 and 67% treatments respectively. The high BA in the unthinned plots should be correlated to the higher number of trees perhectare. Mean DBH values of individual trees ranged between 0.056 m and 0.073 m. The trees in the 67% thinning plots showed the greatest mean stem volume (0.029 m^3 $tree^{-1}$), but without statistical significance compared to 0.017 m^3 $tree^{-1}$ for the other two treatments. Total tree height mean values ranged between 8.85 and 7.46 m. While the average crown length ranged between 5.53 and 6.39 m. Mean specific leaf area (SLA) ranged between 96.4 and 86.8 cm^2gm^{-1} but did not reach any significant difference. This result is in accordance with the findings of Gajardo-Caviedes *et al.* (2005) on the effect of thinning on *Nothofagus dombeyi* (Mirb.) Oerst., in which, the specific leaf area did not vary between treatments. Sala *et al.* (2005) reached the same conclusion as they were studying the effect of thinning on ponderosa pine. In contrast to BA, volume per unit area was not significantly affected by thinning. The highest mean value was scored for the unthinned (95.84 m^3 ha^{-1}) while, the 50% treatment (47.76 m^3 ha^{-1}) was the lowest.

The positive significant effect of the treatments on foliage AGDM as well as CrD encountered herein suggests that, an increase in the AGDM of all other tree components should occur due to the increase in photosynthetic potential of trees. Those findings are in accordance with the observations of Wallentin (2007) on the thinning response of *Picea abies* (L.) H. Karst. trees, who concluded that short-term thinning reactions at stand level must be negative. He observed that the canopy layer in the stand must either increase in size, effectiveness, or both, before growth can be increased. The data obtained by Chiang, *et al.* (2008) in their work on a natural stand of *Acer rubrum* L. indicated that there was a transient impact of thinning causing a reduction of the aboveground net primary production.

It must be stated that the limiting soil characteristics of the plantation site may have added a delaying effect of thinning on biomass production. A better influence of thinning could be achieved under better site conditions.

Allometric Equations

Allometric equations were developed relating stem volume (V) and DM of individual tree components to easily measured parameters, namely, diameter at breast height (DBH) and total height (H). The equations presented in Table 5 and illustrated in Fig. 1, were chosen from several models that were established using the collected data. The highest coefficient of determination (R^2) and standard error of estimate (S_{EE}) were the basis for choosing the appropriate equation for each AGDM component.

Table 5. Allometric equations for different dry matter components and total dry matter of individual trees.

Equation	n	R^2	S_{EE}
#Sbr = - 0.34+395.34** DBH^2	26	0.882	33.11
Bbr = -1.78+1274.21** DBH^2	26	0.899	98.18
Bark = 0.062+ 74.52** DBH^2	24	0.945	03.82
Wood = 1.08+274.14** DBH^2H	25	0.996	03.98
TDM = 10097.06 $(DBH)^{2.33}$**	21	0.987	00.06
V = 0.32 $(DBH^2H)^{0.88}$**	27	0.990	00.02

**highly significant at 0.01 level of probability.

#Sbr = DM of twigs (kg).
Bbr = DM of branches (kg).
Bark= DM of Stem bark (kg).
Wood= DM of Stem wood (kg).
TDM = Total above ground DM (kg).
V= Stem volume (m^3).

The (R^2) values were 0.882, 0.899, 0.945, 0.996, 0.987 and 0.990 for twigs, branches, bark, stem wood, total DM and stem volume respectively.

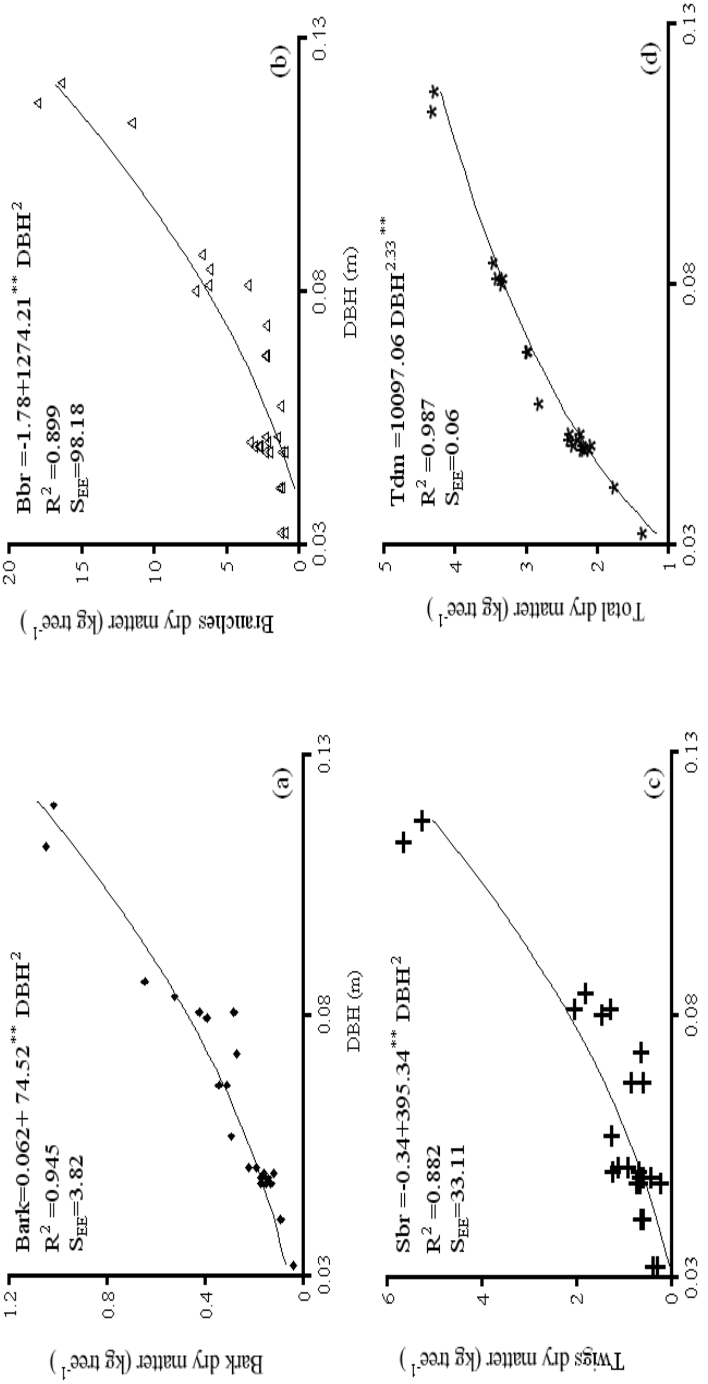

Fig.1. Relationship between diameter at breast height (m) and dry mater (kg tree^{-1}) some tree components of *Conocarpus erectus* Trees after nine years of planting.

The highly significant relationships accomplished herein indicate the possibility of using those equations for the purpose of prediction. As it was mentioned before foliage DM was the only AGDM component that was significantly affected by thinning treatments. In accordance, no pooled regression of foliage DM could be established with any measured tree parameter. Separate regression equations were established for foliage DM in each treatment. The equations presented in Table 6 indicate poor relationships in the unthinned and 50% treatments. Although the relationship in the 67% treatments was significant, R^2 was relatively low (0.525).

Table 6. Allometric equations for foliage DM.

Thinning intensity (%)	Equation	n	R^2	S_{EE}
0	$F = 0.22 + 40.57\ DBH^2$	9	0.287	28.60
50	$F = 0.19 + 91.50\ DBH^2$	8	0.429	39.01
67	$F = 0.22 + 222.41^*\ DBH^2$	9	0.525	86.36

F = foliage DM (kg).

This phenomenon could be attributed to the effect of narrow spacing in the first two treatments. Cole and Ewel (2006) concluded that the ability to predict the biomass of large woody components such as boles tends to be stronger than that of smaller, shorter-lived components such as leaves. They stated that, it is likely that intraspecific competition in densely spaced plantations influences crown geometry and therefore the heterogeneity of leaf biomass from tree to tree.

Conclusion

The effect of thinning, as a silvicultural practice, on biomass production of SRIC buttonwood trees was investigated. AGDM of the different tree components and total AGDM were not statistically different between thinning treatments except foliage DM. Moreover, thinning increased the share of foliage in the total above ground biomass and, in general, improved crown development. Accordingly, we assume that an increase in the AGDM of all other tree components should occur. To determine the effect of thinning treatments on such plantations efficiently, future studies should be carried out after sufficient time intervals following treatments application.

Allometric equations for the prediction of different AGDM components and V were established. Chosen allometric equations related V and DM of individual tree components to DBH or DBH and H. Excluding foliage DM, the highly significant relationships, were not treatment specific. The established equations appropriate for various AGDM components would be a convenient tool for predicting yield and biomass of buttonwood plantations in the western region of Saudi Arabia.

References

Al-Harbi, A. A. A. (2006) Effects of water deficit on the growth and physiological performance of *Conocarpus erectus* and *Eucalyptus microtheca* under field conditions. *M. Sc. Thesis***,** Department of Plant Production, College of Food Sciences and Agriculture, King Saud University, Riyadh, Saudi Arabia.

Al-Humaid, **A.I.** and **Moftah, A.E**. (2007) Effects of hydrophilic polymer on the survival of buttonwood seedlings grown under drought stress, *Journal of Plant Nutrition,* **30**: 53-66.

Al-Solimani, S. G. (2003) Chemical properties of soils and underground water of Hada Al-Sham research station, Kingdom of Saudi Arabia, *J. Environ. Sci., Ain Shams University,* **6:** 257-284.

Al-Solimani, S. G., El-Toukhy, A. and **Al-Zahrani, S.** (2003) Mineral characteristics, classification and evaluation of the soils of Hada Al-Sham research station, Kingdom of Saudi Arabia, *J. Environ. Sci., Ain Shams University,* **6:** 285- 322.

Chiang, J., McEwan, R. W., Yaussy, D. A. and **Brown, K. J. (**2008) The effects of prescribed fire and silvicultural thinning on the aboveground carbon stocks and net primary production of overstory trees in an oak-hickory ecosystem in southern Ohio, *Forest Ecology and Management,* **255:** 1584-1594.

Cole, T.G. and **Ewel, J.J.** (2006) Allometric equations for four valuable tropical tree species, *Forest Ecology and Management,* **229:** 351–360.

Daniel, T. W., Helms, J. A. and **Baker, F. S.** (1979) *Principles of Silviculture*, 2nd Ed. McGraw-Hill, New York, 521 p.

El-Juhany, L. I. and **Aref, I. M. (**2005) Interactive effects of low water supply and high salt concentration on the growth and dry matter partitioning of *Conocarpus erectus* seedlings, *Saudi Journal of Biological Sciences,* **12:** 147-157.

Eriksson, E. (2006) Thinning operations and their impact on biomass production in stands of Norway spruce and Scots pine, *Biomass and Bioenergy,* **30:** 848–854.

Fehrmann, L. and **Kleinn, C.** (2006) General considerations about the use of allometric equations for biomass estimation on the example of Norway spruce in central Europe, *Forest Ecology and Management,* **236:** 412–421.

Gajardo-Caviedes, P. A., Espinosa, M. A., González, U. and **Ríos, D. G.** (2005) The influence of thinning and tree size on the sapwood area / leaf area ratio in coigue, *Canadian Journal of Forest Research,* **35:** 1679-1685.

Geimer, R. L. and **Crist, J. B.** (1980) Structural flakeboard from short-rotation, intensively cultured hybrid Populus clones, *For. Prod. J.,* **30:** 42-48.

Gilman, E.F. and **Watson, D.G.** (1993) *Conocarpus erectus*, buttonwood, *Fact Sheet ST-179,* U.S. Forest Service and Southern Group of State Foresters, Gainesville, FL. 3 p.

Hiratsuka, M., Toma, T., Yamada, M., Heriansyah, I. and **Morikawa, Y.** (2004) A general allometric equation for estimating biomass in *Acacia mangium* plantations, *Proc. of the International Conference on Tropical Forests and Climate Change: Carbon Sequestration and Clean Development Mechanism: 21-22 October, 2003, Traders Hotel, Manila, Philippines*: pp: 212-218.

Juodvalkis, A., Kairiukstis, L. and **Vasiliauskas, R.** (2005) Effects of thinning on growth of six tree species in north-temperate forests of Lithuania, *European Journal of Forest,* **124:** 187-192.

Kramer, P.J. and **Kozlowski, T.T.** (1979) *Physiology of Woody Plants*, Academic Press, New York. p. 811.

Moftah, A.E. and **Al-Humaid, A.I.** (2004) Water requirements and use of Buttonwood (*Conocarpus erectus*) seedlings grown under arid conditions, *Journal of Applied Horticulture,* **6**: 48-52.

Morton, J.F. (1981) *Atlas of Medicinal Plants of Middle America. Bahamas to Yucatan,* C.C. Thomas Pub. Ltd., Springfield, Illinois, U.S.A. 1420 p.

Muñoz, F., Rubilar, R., Espinosa, M. J., Cancino, T. J. and **Herrera, M.** (2008) The effect of pruning and thinning on above ground aerial biomass of *Eucalyptus nitens* (Deane & Maiden) Maiden, *Forest Ecology and Management,* **255:** 365-373.

Nordh, N.E. and **Verwijst**, **T.** (2004) Above-ground biomass assessments and first cutting cycle production in willow (*Salix* sp.) coppice - A comparison between destructive and non-destructive methods, *Biomass and Bioenergy,* **27:** 1– 8.

Peichl, M. and **Arain, M. A.** (2007) Allometry and partitioning of above- and belowground tree biomass in an age-sequence of white pine forests, *Forest Ecology and Management,* **253:** 68-80.

Pilli, R., Anfodillo, T. and **Carrer, M.** (2006) Towards a functional and simplified allometry for estimating forest biomass, *Forest Ecology and Management,* **237:** 583–593.

Piotto, D., Montagnini, F., Ugalde, L. and **Kanninen M.** (2003) Growth and effects of thinning of mixed and pure plantations with native trees in humid tropical Costa Rica, *Forest Ecology and Management* **177:** 427-439.

Rytter, L. (1995) Effects of thinning on the obtainable biomass, stand density, and tree diameters of intensively grown grey alder plantations, *Forest Ecology and Management,* **73:** 135-143.

Sala, A., Peters, G.D., McIntyre, L.R. and **Harrington, M.G. (**2005) Physiological responses of ponderosa pine in western Montana to thinning, prescribed fire and burning season, *Tree Physiol.,* **25:** 339-48.

SAS Institute (2000) *SAS Package Ver. 8,* SAS Institute Inc. Cary, NC, USA.

Sochacki, S.J., Harper, R.J. K. and **Smettem, R.J.** (2007) Estimation of woody biomass production from a short-rotation bio-energy system in semi-arid Australia, *Biomass and Bioenergy,* **31:** 608-616.

Steel, R. G. D. and **Torrie, J. H.** (2000) *Principles and Procedures of Statistics with Special Reference to the Biologic Sciences*, 4^{th} ed., McGraw-Hill, N. Y. U.S.A.

Wallentin, C. (2007) Thinning of Norway spruce, *Acta Universitatis Agriculturae Sueciae,* **29:** 116.

تأثير الخف على الكتلة الحيوية فوق سطح الأرض لأشجار *Conocarpus erectus* L. في المنطقة الغربية من المملكة العربية السعودية

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المستخلص. تقتصر الاستفادة من الأشجار المستجلبة من الخارج إلى المملكة العربية السعودية في الغالب على الاستخدامات البلدية. ومن أجل إقامة مزارع حرجية من هذه الأنواع، ينبغي إجراء دراسات بشأن تأثير المعاملات التنموية على إنتاجية هذه المزارع. في الدراسة الحالية، تم دراسة تأثير ثلاثة معاملات للخف على مزرعة شجرية كثيفة قصيرة الدورة عمرها ٧ سنوات للنوع *Conocarpus erectus* L.، بعد عامين من تطبيق الخف. وكانت المعاملات هي خف صفر و٥٠ و٦٧٪ من الأشجار. وفيما عدا الزيادة في المادة الجافة للأوراق، لم يكن هناك أي تأثير معنوي للخف على المادة الجافة السطحية لمكونات الأشجار الفردية. وقد تراوح متوسط المادة الجافة السطحية الكلية بين ١٥,٧٩ كجم للمعاملة بدون خف و٢٢,٤٤ كجم لمعاملة ٦٧٪. في جميع المعاملات، أعطى خشب الجذع أكبر نسبة من المادة الجافة السطحية، وكانت أعلى قيمة للمعاملة بدون خف (٧١,٧٢ ٪)، والتي اختلفت معنوياً عن المعاملات الأخرى (٦٢,٨٨ و٦٣,٠٥٪).

من بين كل مقاييس أبعاد الأشجار، لم يكن هناك تأثير معنوي للمعاملات إلا علي قطر التاج والمساحة القاعدية للمجموعة الشجرية. وكان لمعاملة الخف ٦٧٪ والمتوسط الأعلى في قطر التاج (٢,١٦ م)، بينما كانت المعاملة بدون خف هي الأعلى في المساحة القاعدية (١٧,٩٣م٢ هكتار⁻١). وتم إنشاء عدة معادلات ألومترية تربط بين المادة الجافة لمكونات الأشجار الفردية وحجم جذعها مع قطرها وارتفاعها الكلي. وباستثناء المادة الجافة للأوراق فإن جميع العلاقات كانت عالية المعنوية. وكانت معاملات التقدير (R^2) هي ٠,٨٨٢ و٠,٨٩٩ و٠,٩٤٥ و٠,٩٩٦ و٠,٩٨٧ و٠,٩٩٠ للمادة الجافة للأغصان والفروع والقلف وخشب الجذع والمادة الجافة الكلية وحجم الجذع على التوالي.