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Effects of Initial Thinning on the Growth and Biomass Characteristics of *Zizyphus spina-christi* Trees

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Abstract: Seedlings of *Zizyphus spina-christi* trees grown from seeds were planted intensively in the field at the Experiments and Research Station of College of Agriculture, King Saud University near Riyadh City. After a year, the trees were subjected to thinning through three consecutive years and evaluated for growth and biomass production. Starting from the second year of thinning, the thinned trees increased stem diameter and all above-ground biomass components. Branches and foliage biomass ratio also increased due to thinning at the expense of stem biomass ratio. Unthinned trees were superior in biomass production after three years of the treatment application.

Key words: *Zizyphus spina-christi*, thinning, growth, biomass production, allocation

INTRODUCTION

The genus Zizyphus belongs to the buckthorn family Rhamnaceae. It is a genus of about 100 species of deciduous or ever green trees and shrubs distributed in tropical and subtropical regions of the world (Johnston, 1963). Zizyphus species have several physiological and morphological characteristics that may contribute to their ability to adapt to arid environment (Depommier, 1988). Some species occur on nearly every continent whereas other species like *Zizyphus spina-christi* is restricted in its distribution to distinct areas such as eastern Mediterranean and Arabian Peninsula (Arndt *et al.*, 2001). *Zizyphus* species are used by a great majority of the rural population in arid regions to meet their daily household requirements such as food, fuel, fodder, fertilizer, building materials and medical herbs (Arndt *et al.*, 2001). The fruits are edible, leaves and twigs can be used as a high nutritional fodder for livestock. Zizyphus species also can contribute to control the rate of decertification and soil erosion (Khoshoo and Subrahmanyam 1985; Depommier 1988; Sena *et al.*, 1988).

However, achieving any of the above mentioned prepossess requires different silvicultural practices in terms of planting density, pruning, thinning etc. Planting density influences the rate of increase in stem diameter and height and consequently tree size and biomass. In a field experiment, initial spacing between trees affected the growth of Leucaena trees through both diameter and height growth rate; they increased with increasing spacing; with larger effects upon that of diameter on the wider spacing (El-Juhany and Aref, 2001). The growth response of individual trees following thinning may be due to both above- and below-ground factors (West and Osler, 1995). Above ground, the amount of radiation available to each tree canopy is increased as thinning reduces inter-tree shading, so that more photosynthesis, hence more growth, may occur (Donner and Running 1986; Ginn *et al.*, 1991). Below ground, available resources (water and nutrients) are exploiting by less number of trees (Aref *et al.*, 1999).

The objectives of this study are to evaluate the effects of thinning on the growth and above-ground biomass production and partitioning among tree parts of *Zizyphus spina-christi* trees planted in intensive short rotation culture.

MATERIALS AND METHODS

Site characteristics: 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).

Cultural details: 330 seedlings were planted in the field in October 1998. The seedlings 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 (26.25 m long × 17.5 m wide), with a starting density of 6400 trees ha^{-1}. The trees were irrigated once a week in winter and every four days in summer throughout the course of the experiment.

Statistical design: The planted area was divided into three blocks, each had two experimental plots using a randomized complete block design.

Thinning technique: 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 trees ha^{-1} in the thinned plots. The other three plots were kept without thinning up to the end of the experiment.

Measurements of diameter and height: For the purpose of monitoring the growth of trees, five trees from both thinned and unthinned plots were chosen randomly for periodical measurements of stem diameter and height. Stem height was measured from the soil surface to the top of tree while stem diameter was measured at a previously marked point at 30 cm on the bole above soil surface. These measurements were recorded every 3 months from October 1998 up to February 2003. Both height and diameter increment for each period were calculated.

Biomass determination: In February 2001 and February 2002, 18 trees were felled from both the thinned and unthinned plots (9 trees from each plot) and used for biomass determination. In February 2003, the number of sampled trees taken from unthinned plots was increased to 21 trees. The felled trees were separated into stem, branches, leaves and fruits. Samples from each component were taken for dry weight determination. The samples of leaves and fruits were oven dried at 70°C for 24 h, while those of stem and branches were dried at 102 ±3°C. Total tree aboveground dry weight for each tree were calculated as well as biomass allocation to each component. Aboveground dry biomass per hectare for both thinned and unthinned plots was estimated as the average tree aboveground dry biomass multiplied by the number of tree in each plot.

Statistical analysis: The obtained data were statistically analyzed through analysis of various procedure using SAS computer programme (SAS Institute, 1987). The means of treatments for different measured variables were distinguished by L.S.D. test.

RESULTS

Growth of height and diameter: The analysis of variance for both height and diameter (Table 1) revealed highly significant differences for diameter on the third year only ($P<0.0001$). Means of stem diameter were 11.76 and 6.67 cm for thinned and unthinned trees, respectively. Stem height did not change due to thinning (Table 1). On the other hand, both height and diameter increment were significantly affected by thinning ($P<0.05$) and ($P<0.0001$), respectively and by time intervals ($P<0.0001$). Thinned trees had higher average values for both height and diameter increment. The averages of both traits were 0.45 m and 0.82 cm on three months period basis, respectively comparing with 0.33 m and 0.46 cm for the same traits in unthinned trees on the same time period.

The greatest average values of both diameter and height increments were attained in August-November periods in years of 1999, 2000 and 2002 (Table 2). The trend of height increment illustrated in Table 2 revealed that the average values of thinned trees were higher than those of unthinned trees, but both shared the same low and high peaks of growth through the consecutive periods of measurements. Height increments from February to August were slow comparing to that from August to November. On the other hand, Table 2 shows that the average diameter increment values of thinned trees were significantly higher ($P<0.0001$) than those of unthinned trees. The trend of diameter increment in the thinned trees followed almost a systematic growth rotation through the year, where there was a sharp increase through August-November period then a sharp decline through November-February period followed by constant increment through February-May period. The trend of unthinned trees traced the same pattern with little delay and in the second peak of growth and failed to complete the growth increment in the third peak of growth.

Biomass production and allocation: Table 1 shows significantly higher average values of total aboveground dry biomass ($P<0.0001$) and its components (stem, ($P=0.0002$); branches, ($P<0.0001$); foliage, ($P<0.0001$) and fruits, ($P=0.002$) for thinned comparing with unthinned plots of Zizyphus spina-christi trees only by February 2003. Averaged values were 13.75 and 4.92 kg for stem; 11.63 and 2.98 kg for branches; 6.19 and 1.48 kg for foliage; 0.79 and 0.12 kg for fruits and 32 kg and 9.5 kg for total aboveground biomass in thinned and unthinned plots, respectively.

Allocation of dry biomass into different aboveground components as a percentage of total aboveground dry biomass for both thinned and unthinned plots from Feb 2000 up to Feb 2003 is illustrated in Table 3. The trees start with lower percentages in the stem and branches and higher percentage in foliage. When trees get older the percentage of foliage decreased, while stem and branches

Table 1: Means of stem diameter, height and dry biomass of thinned and unthinned *Zizyphus spina-christi* trees through four years of treatment

					Biomass (kg tree^{-1})					Total biomass
Year	Treatment	No. of trees	Diameter (cm)	Height (m)	Stem	Branches	Foliage	Fruits	Total	(kg ha^{-1})
2000	Unthinned	9	2.93	3.97	1.05	0.36	1.01	0.47	2.89	18.5
	Thinned	9	-	-	-	-	-	-	-	-
2001	Unthinned	9	*5.81[a]	5.22[a]	2.95[a]	1.46[a]	1.89[a]	0.25[a]	6.54[a]	41.9
	Thinned	9	5.51[a]	4.40[a]	2.06[a]	1.51[a]	1.77[a]	0.17[a]	5.52[a]	17.7
2002	Unthinned	9	6.25[a]	6.36[a]	4.14[a]	3.01[a]	2.15[a]	0.31[a]	9.61[a]	61.5
	Thinned	9	8.55[a]	6.36[a]	6.08[a]	5.38[a]	3.96[a]	0.19[a]	15.61[a]	25.0
2003	Unthinned	21	6.67[b]	6.76[a]	4.92[b]	2.98[b]	1.48[b]	0.12[b]	9.50[b]	60.8
	Thinned	9	11.76[a]	7.76[a]	13.75[a]	11.63[a]	6.19[a]	0.79[a]	32.36[a]	51.8

Table 2: Stem diameter and height increment of five years old *Zizyphus spina-christi* trees after three successive thinning operations from February 2000. Values are mean of five trees

	Diameter increment (cm tree^{-1})		Height increment (m tree^{-1})	
Period of growth	Thinned	Unthinned	Thinned	Unthinned
May 1999 - August 1999	1.37	0.73	1.07	0.83
August 1999 - November 1999	1.88	1.27	1.50	0.86
November 1999 - January 2000	0.71	0.22	0.33	0.43
January 2000 - May 2000	0.71	0.22	0.33	0.26
May 2000 - August 2000	0.94	0.30	0.44	0.17
August 2000 - November 2000	1.11	0.78	0.63	0.73
November 2000 - February 2001	0.57	0.97	0.21	0.12
February 2001 - May 2001	0.60	0.38	0.25	0.18
May 2001 - August 2001	0.90	0.10	0.15	0.13
August 2001 - December 2001	0.53	0.13	0.10	0.05
December 2001 - February 2002	0.67	0.18	0.05	0.18
February 2002 - May 2002	0.88	0.43	0.27	0.07
May 2002 - August 2002	0.75	0.20	0.33	0.15
August 2002 - November 2002	0.38	0.15	0.80	0.38
November 2002 - March 2003	0.33	0.80	0.33	0.23
Mean	*0.95[a]	0.52[b]	0.52[a]	0.36[b]
L.S.D. at P<0.05 (for period within treatment)	1.002	1.002	0.486	0.486
L.S.D. at P<0.05 (for periods)	0.508		0.344	

Table 3: Allocation of aboveground biomass of *Zizyphus spina-christi* trees into stem (stem weight ratio, SWR), branches (branch weight ratio, BWR) and leaves (leaf weight ratio, LWR) in thinned and unthinned plots over four years. Values are means of 9 trees

Year	Treatment	SWR	BWR	LWR
2000	Unthinned	41.51	10.01	48.69
2001	Unthinned	*47.47[a]	21.90[a]	30.79[a]
	Thinned	36.30[b]	26.90[a]	36.87[a]
2002	Unthinned	47.74[a]	27.15[a]	25.16[a]
	Thinned	39.86[a]	31.94[a]	28.22[a]
2003	Unthinned	54.75[a]	29.44[b]	15.84[a]
	Thinned	42.74[b]	35.26[a]	22.01[a]

* Means followed by the same raised letters in any row are not significantly different at P<0.05 according to L.SD. test

percentages increased. By February 2003, the trees in the thinned plots allocated more biomass to their branches and foliage (including fruits) at the expense of stem comparing to the trees in the unthinned plots. The effect of thinning on the third year (2003) was more pronounced (P<0.0001) in changing the relative distribution of these components within trees (Table 1). It increased the branches weight ratio from 29.44 to 35.26% and foliage ratios (including fruits) from 15.84 to 22.0% at the expense of stem weight ratio, which decreased from 54.75 to 42.74%, compared with the unthinned trees.

Evaluating the potential of *Zizyphus spina-christi* plantation for biomass production at different levels of thinning and through time showed that the thinned plots produced total biomass of 17.7, 25 and 51.8 ton ha^{-1} which resemble 42.2, 40.7 and 85.2% of the unthinned plots after three consecutive thinning operations. This was associated with number of trees was half and quarter per hectare as much as those in unthinned plots in the second and third year after thinning, respectively (Table 1).

DISCUSSION

Effects of thinning on the growth of height and diameter: Thinning had marked effects on the growth and biomass characteristics of Zizyphus spina-christi trees only by the third year, except stem height. De Montigny and Stearns-Smith (2001) found that thinning had no significant effect on average height while it had a significant and dramatic effect on average diameter of Douglas–fir trees. Moreover, De Montigny and de Jong (1998) stated that thinning can promote diameter growth and had no effect on the stand height. However, thinning had a gradual effect from year to the next since the second thinning. For instance, the differences between average values of stem diameter in both thinned and unthinned trees were almost similar in February 2001 then increased to 2.3 cm in February 2002 and to 5 cm in February 2003.

The variations observed for unthinned trees in diameter increment curve (Table 2) such as the delay and in the second peak of growth and failure to complete the third peak compared with thinned trees may be due to the high relative competition of these intensive cultivation on the site resources. However, Zizyphus trees were reported that they develop a deep and extensive root system that insures its ability to exploit deep water resources, thereby maintaining a sufficient water and nutrient supply for prolonged periods when the upper soil layers are drying out (Anonymous, 1976; Depommier, 1988).

Biomass production and allocation: Increasing total aboveground biomass and it components of Zizyphus spina-christi trees in the present study concurs with the results of Mrling (1999) who found that the biomass production per tree of Scots pine was increased in all fraction by thinning. These superior average values for thinned trees can be explained by the ability of the remained trees to invest the site resources (water, minerals) and the live branches will have access to more light and hence continue to grow. Thinning opens up the stand, affording individual trees less competition for water, light and nutrients. The capacity of the remaining trees to take advantage of the decreased competition is largely a function of the size, vigour and distribution of their crowns. These factors, in turn depend on the site quality, the stand history and stage of development (Oliver and Larson, 1990; McWilliams and Therien, 1996).

The results of biomass production per unit area suggest that thinned plots of *Zizyphus spina-christi* under the previous stated conditions can reach their optimum potential productivity after three years from the first thinning, with less number of trees having better stem quality and good branching. These findings were supported by De Montigny and de Jong (1998) and De Montigny and Stearns-Smith (2001) where they found that thinning increased individual–tree volume but decreased total stand volume of mixed stands of Western Hemlock-Stika Spruce and Douglass–fir trees, respectively.

Changing the allocation of biomass to different aboveground tree components due to thinning was indicated by increases in both branches and foliage proportions at the expense of stem proportion across all the years (2001-2003). However, These observations reflect the truth that trees under thinning conditions invest their potential to develop more branches and foliage in expense of stem. These observations were reported by Chen-nan Lo-Cho *et al.* (1997) on the effect of thinning on the growth of Taiwan Red Cypress.

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