Effect of planting density on *leucaena leucocephala* forage and Woody stems production under arid dry climate

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Abstract**—** *Lack of year round supply of forage for animal feed is common in most parts of dry lands. leucaenaleucocephala is one of most widely used dry season tree legume forage. In this study, the effect of planting density on forage and woody stems production was investigated. Three different planting spacing corresponding to (40X40 cm, 60X60 cm and 80X80 cm) were applied to tests its effects on tree growth and yield. Tree height and diameter were measured before every cutting harvest. In addition to that fresh and dry matter production of both stems and forage (tons/ha), stems, and leaves dry weight ratios over time were determined. The study revealed that different planting densities were resulted in very high significant effects on forage and stem production. Tree height was affected by planning density in most of the harvests, while diameter showed significant difference among the treatments in only one harvest. Planting trees at 40 cm distance produced higher forage yield with smaller woody stems sizes, whereas 60 and 80 cm spacing resulted in lesser forage yield, but with bigger stems size. This indicates that planting trees at closer spacing produce higher wood and forage yield, but the wood with smaller sizes. There is also, observed seasonal variation in production in which hot weather lowered yield. The stems and leaves dry matter ratio revealed that leaves production is slightly higher than stem production and were not affected by planting density. The results conclude that planting leucaena in closer spacing in arid lands will supply a considerable amount of forage as supplementary feed in addition to wood that can be used for different purposes.*

Keywords**— *planting density, forage production, wood stems.***

I. INTRODUCTION

Leucaena is fast growing multi-purpose drought resistance tree species (Yige et al., 2012). It iswidely cultivated around the World for its highest wood production and wide ranges of uses (Arbonnier, 2004). Leucaenais classified among the most widely used forage tree legume (Shelton and Brewbaker, 1998). When pruned in a regular basis it can produce large quantities of palatable, digestible and nutritious foliage for ruminants. Under closer spacing and consecutive cuttings leucaena can yield forage of up to 40 tons dry matter/ ha (Wilkins, 2000). Supplementing animal fed with dried leucaena leaves will lead to higher weight gain (Rubanza et al., 2007). The leaves meal also, when combined with cassava base supplement enhanced feed intake, nutrient digestibility and rumen fermentation (Kang et al., 2012). It is believed that the presence of amino acid mimosine in the foliage may affect fodder quality (Ilham et al., 2015). However, ruminants rarely have problems with mimosine, because microbes in first stomach (rumen) alter mimosine to a 3,4-dihydroxy pyridine which is then broken down further into nontoxic compounds (Chaudhary and Al-Jowaid, 1999). Where the wood produced from leucaena have very high feasibility for many wood industrial products (Feria et al., 2011; hindi et al., 2010). The seeds are potential fermentable growth source for production of extracellular lipase enzyme (Singh et al., 2014). The seeds also, contain high properties galactomannan soluble polysaccharide (Nwokocha and Williams 2012). Further rolesof the species as multiple purpose trees is a good candidate for sustainable animal farming system by increasing livestock live gain and in the same time reducing greenhouse gas emissions (Harrison et al., 2015).The tree was used as agroforestry tree in many countries, in windbreaks, shade and roadside (Debra and Justin, 2013; Elfeel et al., 2013).

Normally under dry land conditions, there is shortage of year round forage for livestock. Dried leucaena is used during the dry season as conserved hay for feeding dairy cows (Maasdorp et al., 1999). The objective of this study is to investigate the effect of planting density on forage and woody stem production. The aim is to determine best planting spacing that produce large amount of forage in the same time the remaining woody material can be used as fuel or other industrial purposes.

II. MATERIALS AND METHODS

2.1 Experimental site

The location of the experiment is in King Abdulaziz University, Agricultural Experimental Farm. The experiment was carried in hot dry conditions of Western KSA under drip irrigation system at frequency of once every on week.

2.2 Experimental design

The experimental design used is factorial randomized complete block design with three replicates. The main factors are three trees planting spacing corresponding to 40X40 cm, 60X60 cm and 80X80 cm. In each treatment per each block, the plots are composed of three rows with 10 trees in each row (30 trees per plot).

2.3 Tree height and root collar diameter

To measure height and diameter five trees per each treatment in each plot in the middle row were assigned for measurements (from tree number 3-7 in the row. If one tree is missing, we continue to select tree number 8 instead. Then height and root collar diameter were measured before each cutting harvest four times.

2.4 Fresh and dry materials production

For determination of stems, leaves and total fresh and dry weights, the five trees sampled for height and diameter measurements were cut. Then the trees were separated into leaves and shoots and immediately weighed fresh. The samples were then oven dried in 65^{o} C temperature for 72 hours to determine dry weight. To calculate fresh and dry matter production per hectare, first we estimated the average survival rate in all plots (range from 90.5 to 93%). Then we calculated the average number of trees per hectare in all treatments on the basis of 90% survival. The number of trees per hectare were multiplied by 90% giving (56,250, 25,000 and 14,063 trees) for 40, 60, 80 cm spacing respectively. Afterwards the average fresh and dry weights per tree were multiplied by respective average number of trees per hectare for each spacing to obtain production per hectare. After each cut the trees were allowed to grow for four months before the next cut. The total harvests done were four.

2.5 Stems and leaves dry matter ratios

Stems and leaves dry matter ratios were calculated by dividing average dry weight by total dry weight per tree in each treatment.

2.6 Statistical analysis

Analysis of variance was performed to test effects of mean treatment on the studied parameters and the means were separated by new Duncan’s multiple range tests using statistical analysis system version 9.2, (SAS institute, 2014).

III. RESULTS AND DISCUSSION

3.1 Height and root collar diameter

The current study revealed that tree height was statistically differed among the three spacing applied in most harvests. Whereas the root collar diameter was significantly differed only in the first initial measurement made in the first cutting harvest (Table 1). In the next harvests, when the trees cut to the ground in a uniform levels all the treatments produced the same level of diameter. The observed difference in height may be related to the competition between trees as the result of spacing. In most harvests, height growth was not showed any significant difference between 60 and 80 cm planting distance. However, they are significantly higher than plots planting with 40 cm spacing between trees. The same growth trend was observed in diameter in which planting trees at 60 and 80 cm between trees resulted in higher diameter growth compared to 40 spacing in all harvests.

3.2 Fresh and dry materials production

The data presented in (Table 1 and 2) showed that both stem and leaves fresh and dry matter production was very highly significantly differed among the three planting spacing applied. During the initial cutting (harvest 1) 60 produced higher fresh and dry weight materials. However, when the trees were cut to the same level and allow to grow (harvests 2-4), 40 meter spacing resulted in significantly higher production compared to the other spacing. The season also, may have some effect in fresh and dry biomass production. Production was high in harvest two (beginning of March), declined in harvest three (beginning of June) and increased again in harvest four (beginning of November). The effect of the three planting distance used was resulted in very high variation in total fresh and dry biomass yield (Table 4).The highest forage produced under 40 cm distance treatment accompanied by less diameter, reflects that planting trees at closer distance will yield more tender forage. However, planting trees at wider spacing (60 and 80 cm spacing) means more wood material, but may be with less forage quantity and quality.

TABLE 1
EFFECT OF PLANTING DENSITY ON *LEUCAENA LEUCOCEPHALATREE* HEIGHT (HT) AND ROOT COLLAR DIAMETER (RCD)

Spacing	Harvest 1		Harvest 2		Harvest 3		Harvest 4	
	HT (m)	RCD (cm)	HT (m)	RCD (cm)	HT (m)	RCD (cm)	HT (m)	RCD (cm)
40 cm	1.87$_b$	1.39$_b$	2.10$_a$	1.70$_a$	1.95$_b$	1.03$_a$	2.17$_b$	1.56$_a$
60 cm	2.74$_a$	2.28$_a$	2.10$_a$	1.76$_a$	2.14$_a$	1.10$_a$	2.53$_a$	1.68$_a$
80 cm	2.54$_a$	2.46$_a$	2.26$_a$	1.89$_a$	2.07$_a$	1.08$_a$	2.40$_a$	1.67$_a$
D. F.	2	2	2	2	2	2	2	2
F. value	29.39***	19.23***	2.39	0.76	4.10*	0.92	9.53**	1.63

*** = p ≤ 0.05 ** = p ≤ 0.01*** = p ≤ 0.001**

TABLE 2
EFFECT OF PLANTING DENSITY ON *LEUCAENALEUCOCEPHALA* STEMS FRESH AND DRY MATERIAL PRODUCTION (TONS/HA)

Spacing	Harvest 1		Harvest 2		Harvest 3		Harvest 4	
	FW (ton/ha)	DW (tons/ha)	FW (ton/ha)	DW (tons/ha)	FW (ton/ha)	DW (tons/ha)	FW (ton/ha)	DW (tons/ha)
40 cm	16.46$_{ab}$	6.50$_{ab}$	22.48$_a$	8.37$_a$	18.13$_a$	7.19$_a$	26.92$_a$	10.64$_a$
60 cm	22.01$_a$	8.60$_a$	16.11^b	5.61$_b$	12.83$_b$	4.90$_b$	21.73$_b$	8.45$_a$
80 cm	10.73$_b$	4.19$_b$	12.40$_b$	4.26$_b$	8.32$_b$	3.01$_c$	15.42$_b$	5.90$_b$
D. F.	2	2	2	2	2	2	2	2
F. value	5.51**	5.46**	5.69**	7.95***	9.84***	12.74**	7.16**	9.33***

*** = p ≤ 0.05 ** = p ≤ 0.01*** = p ≤ 0.001**

TABLE 3
EFFECT OF PLANTING DENSITY ON *LEUCAENALEUCOCEPHALA* FORAGE FRESH AND DRY MATERIAL PRODUCTION (TONS/HA)

Spacing	Harvest 1		Harvest 2		Harvest 3		Harvest 4	
	FW (ton/ha)	DW (tons/ha)	FW (ton/ha)	DW (tons/ha)	FW (ton/ha)	DW (tons/ha)	FW (ton/ha)	DW (tons/ha)
40 cm	14.28$_{ab}$	4.48$_{ab}$	32.25$_a$	10.03$_a$	21.83$_a$	6.84$_a$	33.03$_a$	10.59$_a$
60 cm	18.94$_a$	5.88$_a$	23.34$_b$	6.64^b	17.86$_a$	5.27$_b$	27.61$_a$	8.52$_b$
80 cm	10.44$_b$	3.23$_b$	18.11$_b$	5.31$_b$	11.11$_b$	3.24$_c$	18.89$_b$	5.66$_c$
D. F.	2	2	2	2	2	2	2	2
F. value	4.75**	4.68**	8.21**	11.61**	9.77**	15.60**	11.27**	17.38**

*** = p ≤ 0.05 ** = p ≤ 0.01*** = p ≤ 0.001**

TABLE 4
EFFECT OF PLANTING DENSITY ON *LEUCAENALEUCOCEPHALA* TOTAL FRESH AND DRY SHOOT MATERIALS PRODUCTION (TONS/HA)

Spacing	Harvest 1		Harvest 2		Harvest 3		Harvest 4	
	FW (ton/ha)	DW (tons/ha)	FW (ton/ha)	DW (tons/ha)	FW (ton/ha)	DW (tons/ha)	FW (ton/ha)	DW (tons/ha)
40 cm	30.74_{ab}	10.98_{ab}	54.73_{a}	18.41_{a}	39.96_{a}	14.05_{a}	60.00_{a}	21.24_{a}
60 cm	40.96_{a}	14.49_{a}	39.45_{b}	12.25_{b}	30.69_{a}	10.18_{b}	49.33_{a}	16.97_{b}
80 cm	21.17_{b}	7.44_{b}	30.51_{b}	9.57_{b}	19.43_{b}	6.31_{c}	34.32_{b}	11.51_{c}
D. F.	2	2	2	2	2	2	2	2
F. value	5.28**	5.26**	7.24**	9.84***	10.31***	14.79***	9.30**	12.81***

*** = $p \leq 0.05$ ** = $p \leq 0.01$*** = $p \leq 0.001$**

3.3 Stems and leaves dry matter ratios

Both stems and leaves dry matter ratios were not statistically differed between the three planting spacing used in all harvests (Table 5). However, generally in the first harvest the stem ratio was higher than leaves. However, in all subsequent harvests leaves dry matter ratio was slightly higher than those of stems. This was resulted in higher forage production than woody part production. In all harvests after the initial cutting 40 planting distance obtained higher leaves ratio compared to the two other spacing. This confirms the facts that closer planting spacing will produce more forage yield with tender leafy material.

TABLE 5
EFFECT OF PLANTING DENSITY ON *LEUCAENALEUCOCEPHALA* STEMS DRY MATTER RATIO (SDM) AND LEAVES DRY MATTER RATIO (LDM)

Spacing	Harvest 1		Harvest 2		Harvest 3		Harvest 4	
	SWR	LWR	SWR	LWR	SWR	LWR	SWR	LWR
40 cm	0.59_{a}	0.41_{a}	0.44_{a}	0.56_{a}	0.50_{a}	0.50_{a}	0.49_{a}	0.51_{a}
60 cm	0.58_{a}	0.42_{a}	0.45_{a}	0.55_{a}	0.48_{a}	0.52_{a}	0.50_{a}	0.50_{a}
80 cm	0.56_{a}	0.44_{a}	0.44_{a}	0.56_{a}	0.47_{a}	0.53_{a}	0.51_{a}	0.49_{a}
D. F.	2	2	2	2	2	2	2	2
F. value	1.68	1.68	0.37	0.37	1.60	1.46	0.51	0.41

IV. CONCLUSION

The current study highlights the importance of planting leucaena in closer spacing to provide a good quantity of forage and the remaining woody stems can be utilized for any other wood industrial purposes. Planting trees at 40X40 cm spacing produced higher forage and stem yield, however, the stems with smaller sizes. Whereas 60 spacing obtained lesser yield but the stems with bigger sizes. The leaves dry matter ratio is slightly higher than stems dry matter ratio and were not affected by planting density treatments.

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