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INTERSPECIFIC INTERACTIONS AND PRODUCTIVITY OF *LEUCAENA LEICOCEPHALA AND CLITORIA TERNATEA* UNDER ARID LAND MIXED CROPPING

A. A. Elfeel , A. A. Bakhashwain and R. A. Abohassan

Department of Arid land Agriculture, Faculty of Meteorology, Environment and Arid Land Agriculture, King Abdulaziz University, Jeddah, Saudi Arabia
Corresponding author email: aidris@kau.edu.sa

ABSTRACT

Leucaena leicocephala - Clitoria ternatea intercropping under arid dry saline soils was carried out during the period 2010-2012. The aim was to test the effect of tree/ crop productivity and interactions. Crop parameters measured were; relative growth rate (RGR), forage yield, quality and stomatal conductance (gs). Where tree parameters are; height and diameter growth and increase per month. In addition to tree and crop leaf area index (LAI) and soil chemical properties. The study showed that intercropping resulted in reduced crop forage yield and RGR, compared to sole crop. While, protein and most of the minerals were higher and fiber was lower in intercropped forage. Tree growth was remarkably higher under intercropping compared to sole crop. Strong relationship between LAI with tree and crop productivity was observed. Higher values of LAI were associated with higher crop and tree growth. Crop g_s was significantly higher in sole crop compared to intercrop, whereas lower g_s values were observed in mixed plots with higher tree LAI. Soil organic matter was higher in mixed cropped plots associated with lower soil EC and Na and Higher N, K, Ca and Mg. The study concluded that the presence of *Clitoria* had beneficial effects on tree growth, where the trees had negative effects on crop forage productivity and RGR.

Key words: LAI, stomatal conductance, intercropping, productivity.

INTRODUCTION

About 40% of the World' surface area are dry lands, which are sensitive to many land use practices and shortage of water limiting agricultural production (Jama and Zeila, 2005). Almost, the entire land area of Saudi Arabia is dry arid lands with very limited rainfall (Abo-Hassan and Tawfeeg, 2006) and scarce forest cover (FAO, 2011). Most of the Western Part of Saudi Arabia has been classified as hyper arid or arid lands, except the mountainous areas which are classified as semi arid (Subyani *et al*, 2010). To develop these fragile lands sustainably agroforestry system should be an integral part of its farming system (FAO,1993). Total improvement of agroforestry to the farming systems can be described by means of crop yield, the yield of tree products and its effects on land quality (Van Noordwijk, 1996). The importance of agroforestry as a land use system is reflected in sustainable agriculture production, in addition to issues related to climate change, since agroforestry systems are potential carbon sinks (Albrecht and Kandji, 2003). All these factors call for the development of sustainable integrated crop production systems. This can be achieved by mixed cropping of crops and trees that can provide better land use efficiency.

Mixed cropping system can be characterized by the effects of the trees on availability of nitrogen (Kho, 2000), capture and use of the underutilized resources (*Ong et al*, 2004; Jackson *et al.* 2000). Intercropping trees with pasture can result in increased nitrogen availability in the soil and hence pasture productivity (Wilson 1998). It also, improves water use efficiency by reducing water loss (Ong *et al*, 2002). Kinama *et al* (2005), observed lower soil evaporation loss from mulched agroforestry plots as compared to non-mulched plots. Stomatal conductance can be used as measure of plant-atmosphere water status (Karlidaga *et al.*, 2011). Leaf area Index is very important tool to estimate growth, biomass production and yield (Zarade-Valdez *et al.* 2012). LAI was positively correlated with tree and crop growth and yield (Bakhashwain and Elfeel, 2012). Estimation of LAI with plant canopy analyzer proved to be highly correlated with direct methods of LAI measurements (Mason *et al.*, 2012).

Leucaena is a tropical multi-purpose tree native to Central America and cultivated widely around the World for its fast growth, highest wood production and wide ranges of uses (Arbonnier, 2004). The tree was used as agroforestry tree in many countries, in windbreaks, shade and road side. It makes high quality forage production. Under agroforestry *leucaena* is regularly pruned, produces large quantities of palatable, digestible and nutritious foliage for ruminants. Under closer spacing and consecutive cuttings *leucaena* can yield a forage of up to 40 tons dry matter/ ha (Wilkins, 2000).

Clitoria ternatea L. (Fabaceae), known as Butterfly pea, is a summer growing perennial climber, strongly persistent, herbaceous legume. It is a multipurpose shrub widely used as an ornamental, for pastures, green manure, cover crop, to increase soil fertility and to improve yields of crops. Also, has proved to have some medicinal values (Daisy and Rajathi, 2009). It has been introduced in the semi-arid and sub-humid tropics of many countries. Gomez and kalamani (2003), suggested growing *clitoria* on waste lands to narrow the gap of forage demand. Even on infertile soil the plant was persisted under heavy dry season grazing for up to fourteen years (Hall, 1985). It was used in agroforestry to sustain slash and burn and to increase agronomic benefits of crops (Aguiar *et al.*, 2009).

The objective of this study was to test the interspecific intercropping interactions of *leucaena leicocephala* - *clitoria ternatea* in tree and crop productivity and soil amelioration.

MATERIALS AND METHODS

Study area: The experiment was conducted at the Agricultural Research Station, King Abdulaziz University, at Hada Al-Sham during the period (2010 – 2012). The Research Station is located at a distance of more than 100 km at the North-East direction of the Jeddah City (Latitude 21^{o} 48' 3" N, Longitude 39^{o} 43' 25" E, elevation 240 masl). Its area is characterized by a very low rainfall on the range of less than 100 mm/annum) and poor soil (Al-Solimani, 2003).

Experimental Design: The Experiment design was split plot design with three replicates. The main plot treatments were two spacing between trees (2 x 2 meters and 2 x 4 meters, respectively) and the subplots were occupied with the *clitoria* crop. In addition to sole trees and sole crop without trees. Seedlings of *leucaena* took six months at the nursery stage during 2010, after which transferred to the field, allowed to grow for another four months as establishment period then *clitoria* was intercropped. The *clitoria* was planted as row crop in spacing of 40 x 50 cm between plants. The experiment was carried out under drip irrigation system (the water ≈ 1.8 dS/m salinity**).** The data were collected during the period 2011-2012.

Relative growth rate (RGR): RGR was calculated by the general growth equation, RGR= $(W_2- W_1)/ (t_2-t_1)$. Where W_1 and W_2 are crop total dry weights at times t_1 and t_2 (Beadle , 1993).

Clitoria yield: Fresh and dry forage yield (Tons/Hectare/Year), was determined over five consecutive cuttings (harvests). The first harvest started at the age of three months and the subsequent harvests were on the range of approximately seven weeks.

Tree growth: Tree height and diameter were measured at every four months interval. Where height and diameter increase per month was calculated as $m_x – m_i$/number of months (m_x and m_i are final and initial measurements, respectively).

Leaf Area Index (LAI): LAI was measured by plant canopy analyzer (model 2270, LI-COR Biosciences, 2010). The sampling protocol for the *Clitoria* crop was used as one above reading for every four below readings. The four below readings were made between rows (one at the right side of the row, two in the middle of the row and the fourth at the left side of the row). For both above and below readings 180^{o} viewing cap was used in all measurement to limit the azimuthal field of view with in the limits of the plants.

The sampling protocol for the trees was as follows: for every three below readings we measured one above reading. 45^{o} viewing cap was used for both above and below readings. For both trees and the crop a total of three measurements were made at frequency of every one month to measure plant growth development. Mean LAI for each plot plus SEL (standard error of LAI) was directly loaded from analyzer console using (FV 2200 ver. 1.0.0, 2010) software.

Stomatal conductance (g_s): Stomatal conductance was measured with steady state leaf porometer (Leaf Porometer upgraded model SC-1, 2011, Decagon Devices). For each treatment in each block three plants were selected and five leaves were measured per plant. The instrument was calibrated at each measurement as described by the manufacturer. All the measurements were made in the morning between 09:00 to 11:00 o'clock. Fully grown green leaves at the same side for all sampled plants were measured. The measurement was done at the abaxial site of the leaf. A total of three measurements at a frequency of one month interval were made.

Protein content: Nitrogen was analyzed by automated micro-kjeldah and multiplied by 6.25 to get protein content (Horneck and Miller, 1998).

Crude fiber and Ash contents: The crude fiber and ash contents were determined according to the AOAC official methods 978.10 and 942.05 (AOAC, 2006), respectively.

Mineral contents: Leaves and soil mineral contents (Ca, Na, K and Mg) were analyzed using Perkin Elmer model 3110 atomic absorption spectrophotometer (PERKIN ELMER CORP, 1994), according to (Hanlon, 1998). While P was determined according to the method described by (Bhargava and Raghupalhi, 1993). Soil EC was measured with portable EC meter.

Statistical analysis: Analysis of variance of the collected data were carried after applying the ANOVA assumptions and the means were separated and significantly tested by Duncan multiple range test according to El-Nakhlawy (2010), using SAS (Statistical Analysis System, SAS System version 8.1, (2000).

RESULTS

Crop forage dry yield: Analysis of variance showed highly significant affect of intercropping on dry yield production in terms of tons per hectare per year over five cutting harvests (Table 1). In all harvests and in total dry yield production the sole cropping was remarkably higher than intercropped. Total yield production per year in sole crop was 10.7 (tons/ha/yr), whereas in intercropping with 2 x 4 meters spacing the production was 5.59 (tons/ha/yr) and the least production was in intercropping with 2 x 2 meters spacing (5.14 tons/ha/yr). Production trend was higher in harvest one and two and then production tend to decrease with increasing harvests.

Crop forage fresh yield: Similar to the dry yield, intercropping effects on fresh yield was significant (Table 2). The highest fresh yield production was obtained under sole cropping followed by 2 x 4 meters spacing and the least production was under 2 x 2 meter tree spacing. One hectare produced about 35.07 tons/year under sole cropping. Whereas in under cropped produced 16.37 to 14.64 tons/year.

Tree growth: The data revealed that intercropping had highly significant effects on tree height and diameter over sole tree planting (table 3). Likewise, height and diameter increase per month was remarkably higher under intercropping compared to sole crop,

Forage quality: Results in Table 4, showed that the levels of protein contents in *Clitoria* leaves ranged from 26.4% to 25.6%, the ash ranged from 10.8 to 10.1%, whereas the fiber varied from 14.7 to 11.9%. (Table 3). The minerals analyzed also significantly differed between the treatments. The levels of minerals in an intercropping were higher than those in sole cropping.

Crop relative growth: Figure 1, showed highly significant difference on crop relative growth rate. Sole crop showed higher RGR values, where the spacing showed no significant differences.

Tree leaf area index: In general LAI of the trees under intercropping was significantly higher than control. For trees in intercrop 2 x 2 meter has higher LAI than 2 x 4 meter spacing, whereas in control 2 x 4 meter spacing has more LAI values than 2 x 2 meter spacing. The LAI in all treatments increased with time reaching peak in the second month and tend to decline in the third month (Figure 2).

Crop leaf area index: LAI values for *Clitoria* crop was higher in sole crop than under the *Leucaena* tree. Under intercropping 2 x 4 meters spacing obtained the highest values than 2 x 2 meters spacing. Similar to trees LAI for *Clitoria* increased with time reaching the highest values during second month and then decreased in measurement made in the third month (Figure 3).

Stomatal conductance: Stomatal conductance showed significant differences between treatments only on measurement made during third month. Gs were higher at first and second measurements but sharply dropped thereafter measurement (Fig. 4).

Soil properties: Soil analysis presented in Table 5, showed that organic matter was significantly higher under mixed cropping. This was associated with lower soil EC, lower Na and Higher N, K, Ca and Mg in the soil under mixed cropping plots.

Table 1. Effect of *Leucaena leicocephalla - Clitoria ternatea* intercropping on dry yield production (Tons/hectare/yr).

Treatment	Harvest1 Tons/Ha	Harvest2 Tons/Ha	Harvest3 Tons/Ha	Harvest4 Tons/Ha	Harvest5 Tons/Ha	Total yield Tons/Ha
Sole	2.62a	3.22a	1.99a	1.95a	1.01a	10.76a
Spacing 1	1.57b	1.56b	0.97b	0.74b	0.31b	5.14b
Spacing 2	2.03b	1.53b	0.89b	0.81b	0.34b	5.59b
P=	**	*	**	**	**	**
Significance	* = ≤ 0.05		** = ≤ 0.01		ns = not significant	

Means with different letters in the same column are significantly different at 0.05 using Duncan's multiple range test.

Table 2. Effect of *Leucaena leicocephalla - Clitoria ternatea* intercropping on fresh yield production (Tons/hectare/yr).

Treatment	Harvest1 Tons/Ha	Harvest2 Tons/Ha	Harvest3 Tons/Ha	Harvest4 Tons/Ha	Harvest5 Tons/Ha	Total yield Tons/Ha
Sole	10.11a	8.69a	5.29a	6.97a	4.02a	35.07a
Spacing 1	5.46b	4.18b	2.28b	1.95b	0.75b	14.64b
Spacing 2	7.05b	4.31b	1.89b	2.23b	0.87b	16.37b
P=	**	**	**	**	**	**
Significance	* = ≤ 0.05		** = ≤ 0.01		ns = not significant	

Means with different letters in the same column are significantly different at 0.05 using Duncan's multiple range test.

Table 3. Effect of *Leucaena leicocephalla* - *Clitoria ternatea* intercropping on tree growth.

	Height				Diameter			
	Height (meters)		Height increase/month		Diameter (cm)		Diameter increase/month	
	2X2	2X4	2X2	2X4	2X2	2X4	2X2	2X4
Mixed trees	4.23a	4.13a	14.31a	13.39a	5.30a	5.28a	3.08a	2.98a
Sole trees	3.49b	2.98b	7.23b	2.84b	4.49b	3.12b	2.64b	1.78b

Means with different letters in the same column are significantly different at 0.05 using Duncan's multiple range test.

Table 4. Effect of *Leucaena leicocephalla* - *Clitoria ternatea* intercropping on leaves protein, ash, fiber and minerals (N, Mg, Ca, Na, K, P) contents (g/100g).

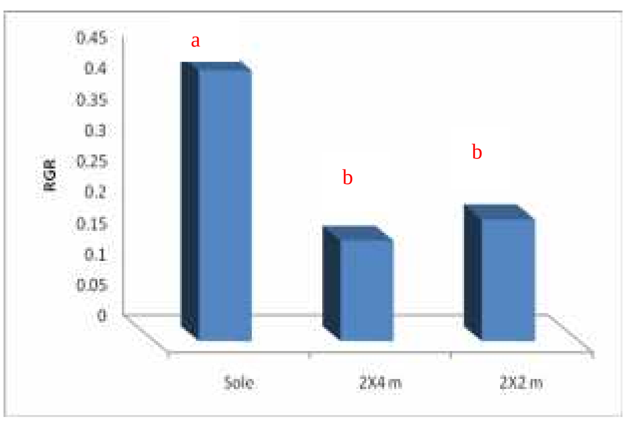
Treatment	Protein	Ash	Fiber	Mg	Ca	Na	K	P
Sole	24.42b	10.19b	14.76a	0.42b	0.26a	0.06a	0.19b	0.36b
Spacing 1	25.59ab	10.76a	14.11b	0.42b	0.25a	0.10a	0.34a	0.44a
Spacing 2	26.42a	10.71a	11.92c	0.44a	0.27a	0.05a	0.21b	0.38b
P=	*	**	**	*	Ns	Ns	*	**
Significance	* = ≤ 0.05	** = ≤0.01	ns = not significant					

Means with different letters in the same column are significantly different at 0.05 using Duncan's multiple range test.

Table 5. Effect of *Leucaena leicocephalla* - *Clitoria ternatea* intercropping on soil chemical properties

Treatment	Organic matter	N g/100g	Electric conductivity	P g/100g	Ca Mg/L	K Mg/L	Mg Mg/L	Na Mg/L
Spacing 1	5.51a	0.026a	1.80a	0.21a	59.34a	22.53ab	46.80a	14.8a
Spacing 2	5.61a	0.025a	1.79a	0.28a	52.07a	27.29a	35.13ab	14.6a
Sole crop	4.78b	0.023a	1.89a	0.21a	39.98b	11.76c	29.17ab	18.1b
Sole tree	4.46b	0.015a	1.86a	0.23a	32.83b	16.49bc	23.17b	17.7b
P=	*	Ns	Ns	Ns	**	**	ns	*
Significance	* = ≤ 0.05	** = 0.01	ns = not significant					

Means with different letters in the same column are significantly different at 0.05 using Duncan's multiple range test.



Means with different letters in different columns are significantly different at (p = 0.05) using Duncan's Multiple Range Test

Fig. 1. Effect of *Leucaena leicocephalla* - *Clitoria ternatea* intercropping on *Clitoria* Relative Growth Rate (RGR)

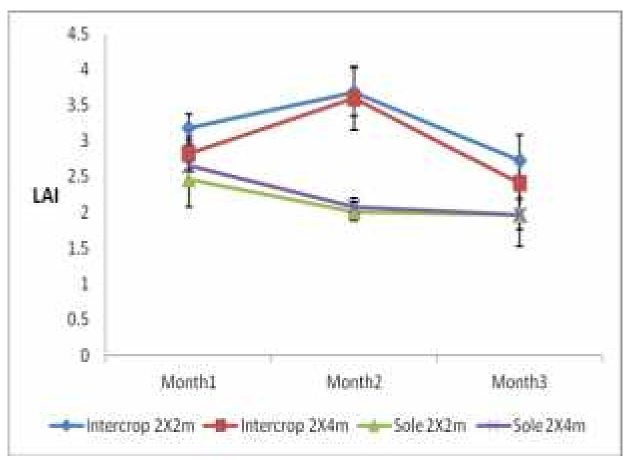


Fig. 2. Effect of *Leucaena leicocephalla* - *Clitoria ternatea* intercropping on tree Leaf Area Index (LAI)

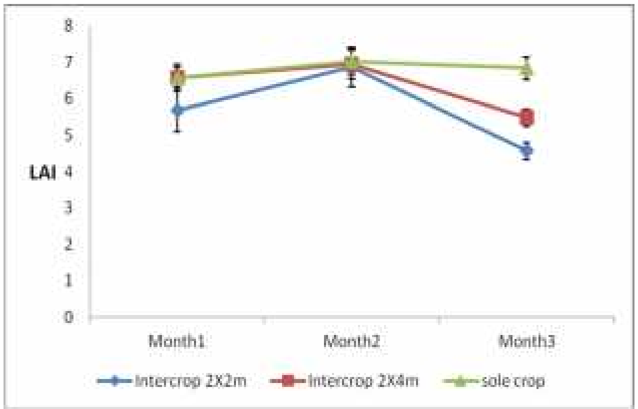


Fig. 3. Effect of *Leucaena leicocephalla* - *Clitoria ternatea* intercropping on *Clitoria* Leaf Area Index (LAI).

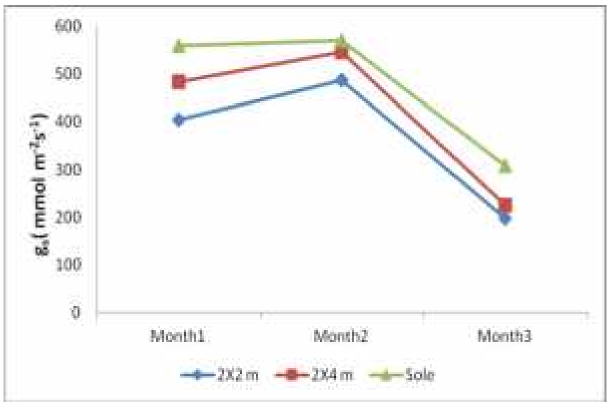


Fig. 4. Effect of *Leucaena leicocephalla* - *Clitoria ternatea* intercropping on Stomatal Conductance (G_S)

DISCUSSION

The net tree - crop effects on mixed cropping system was reduction in *Clitoria* yield, increase in forage quality and slight amelioration of soil properties combined with an increased tree growth and height and diameter increase per month. This may be explained by the positive effects of *clitoria* crop on *leucaena* productivity and higher competition of *leucaena* on the available limited resources resulting in reduced crop relative growth rate and forage production. However, the very high and remarkable tree production and increased forage quality under agroforestry suggested higher land use efficiency or better land equivalent ratio under these dry fragile lands. Moreover, the high and multiple uses of *leucaena* tree highlights the importance of such system under arid conditions. The lower fresh and dry forage production under intercropping compared to the sole crop, may also, be attributed to the fact that under intercropping the *clitoria* plant tend to climb the trees and produce tender and thin stem and twigs, whereas in sole crop the plant tend to spread and develop very strong and hard stems and shoots. Although, this study was not dealt with *leucaena* as fodder tree, but in future studies using both *clitoria* and *leucaena* as forage producing plants the system may be more beneficial. The data obtained showed that in most of the parameters measured the spacing between trees had no significant differences. The too close spacing were used on the assumption that the *clitoria* having climbing habit will enable the plants to climb the trees. However, for future studies using alleys with narrower spacing between trees and wider spacing between alleys may reduce the competition of the trees.

The study revealed a very strong relationship between tree and crop production with LAI. LAI values in both tree and crop was higher with higher tree and crop production. This in accordance to Bakhashwain and Elfeel (2012) and Smethurst *et al.* (2003), who revealed positive relationship of LAI with growth and productivity. Thus LAI can be used as simple tool for estimating amount of the foliage (Arias *et al.*, 2007).

In trees under intercropping plots with narrow spacing of 2 x 2 meter, followed by 2 x 4 meter had higher values of LAI compared to sole crop. This goes in line with tree height and diameter growth. Height and diameter increase per month was higher under 2x2 meter spacing under intercropped plots. This explains the beneficial effects of the presence of *clitoria* on tree growth and production. Earlier findings confirmed the beneficial role of *clitoria* on soil amendment and tree production (Aguiar *et al.*, 2009). In contrast the higher competition of the tree with *clitoria* was reflected in low crop relative growth rate and forage production under 2x2 meters spacing, which was associated with low crop LAI values in these plots.

Stomatal conductance of *clitoria* crop under sole cropping had high values. Although the higher value of stomatal conductance can be reflected in higher Co_2 intake, However, it can also, results in higher transpiration rate and hence loss of water. This may explain the lower conductance under trees, where the trees assist in reduction of transpiration rate (Ong *et al*, 2002). In poor arid environment the added values of the trees in an agroforestry system is the reduced losses of water (Brenan and Kessler, 1997). The reduction of stomatal conductance was also, associated with LAI values. Higher G_s reduction values were recorded in 2 x 2 meter spacing, which had higher tree LAI values, followed by 2 x 4 meter spacing. The sharp decline of G^s in the third reading may be explained by the fact that the third measurement was made at the beginning of the hot summer season where the two seasons were during the warm winter season. The hot summer weather may induced the stomatal to close earlier after sun rise.

The current study also, showed that *leucaena* and *clitoria* mixed cropping system was positively ameliorated the soil properties. Their effects on the agroforestry system was indicated in significant differences in amount of organic matter between intercropped and sole crop sites. In addition, to the increased organic matter, the tree – crop mixture reflected in the improvement of the other soil properties like reduction of soil EC and Na and increase of N, K, Ca and Mg in the soil under mixed cropped plots.

Conclusion: The tree – crop interactions reduced forage yield as affected by tree competition but increased tree growth and forage quality. LAI can be a good indication of crop and tree production. The improvement of the combined system reflected by the higher land equivalent ratio and slight amelioration of the soil properties.

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