Original Article

Journal of Aridland Agriculture 2016, 2: 13-17
http://scienceflora.org/journals/index.php/jaa/
doi: 10.19071/jaa.2016.v2.3000

Effect of nitrogen, shading, and intercropping on alfalfa *Ziziphus* agroforestry system under arid land conditions

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Received: 14.02.2016
Accepted: 30.04.2016
Published: 11.05.2016

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ABSTRACT

To assess the arid lands agroforestry potential, a field experiment was performed at the Agricultural Research Station of King Abdulaziz University, located at Hada Al-Sham during the 2013 and 2014 seasons. Alfalfa was evaluated in a *Ziziphus* agroforestry system at a distance of 1, 2, and 4 m from the *Ziziphus* tree and were supplied with three different levels of nitrogen fertilizer 0, 200, and 400 kg/ha in the form of commercial urea. The fertilizer were subdivided into split doses and applied as manual broadcasting after each cutting. A split-split plot design was used with three replications. Forage growth rate and biomass accumulation were measured at ten different intervals approximately at a period of 30-40 days. Forage was harvested in 10 different cuts, and all this data consisting of plant height, fresh biomass accumulation, and dry biomass accumulation and leaf nitrogen content were also measured. Statistical analysis described significant impact for intercropping, planting distance, and nitrogen fertilizer on all studied traits. The maximum effect of urea fertilizer was documented for the highest dose of 400 kg/ha, but it was statistically non-significant to 200 kg/ha. Distance of planting from the *Ziziphus* tree produced variable trend for all forages at different cut numbers but 2 m produced maximum plant height and biomass accumulation for most of the cut numbers. The interaction of 200 kg N/ha, intercropping, and 2 m distance produced optimum forage growth, and biomass accumulation as compared to the sole plantation under no fertilization.

KEY WORDS: Agroforestry, alfalfa, arid agriculture, intercropping

INTRODUCTION

In the Kingdom of Saudi Arabia, most of the land area are either arid or semi-arid, with very limited forest cover (FAO, 2011). Most of these areas receive less than 100 mm average rainfall per annum (Darfaoui and Assiri, 2010). In addition to this limited amount of rainfall, there is a considerable depletion of ground water resources (Al-Zaharani *et al*., 2011). Thus, sustainable integrated crop production systems that maximize land use need to be developed. Agroforestry is considered to be alternative land use system in arid lands that can achieve this goal (Jama and Ziela, 2005).

In its simplest form, agroforestry can be defined as a sustainable land use management system, in which trees and/or shrubs are deliberately combined with crops and/or livestock to maximize positive interactions between tree and non-tree components (Gold *et al*., 2013). Thus, the term "agroforestry" is a collective name for land-use systems in which woody perennials (trees and shrubs) are grown in association with herbaceous plants (crops, pastures) or livestock, in a spatial arrangement, a rotation, or both (Lundgren, 1982).

Alfalfa (*Medicago sativa* L.) is a perennial herbaceous legume. Due to its high nutritional quality, high yields, and high adaptability, alfalfa is one of the most important legume forages of the world. A major source of protein for livestock, it is a basic component in rations for dairy cattle, beef cattle, horses, sheep, goats, and other classes of domestic animals (Radović *et al*., 2009). It is cultivated in more than 80 countries in an area exceeding 35 million ha (Radović *et al*., 2009). World production of alfalfa was around 436 million tons in 2006 (FAO, 2006). *Ziziphus*, the shrub or tree is spinous, but occasionally unarmed.

Branchlets are densely white pubescent, especially when young and tend to be zigzag. Plant height can vary from 3-4 to 10-16 m or more although trees of 20 m are rare.

The present study was being conducted to investigate the integration of three forage crop alfalfa (*M. sativa*) in agroforestry system with *Ziziphus* trees (*Ziziphus jujuba*) under the western Saudi Arabia condition. Alfafa is a very well-known forage crop of very high nutritive value widely used in KSA (Abusuwar and Bakhashwain, 2012). Hence, the current study was planned (1) to assess the effect of *Ziziphus* trees and N fertilization on forage crops performance and yield, (2) maximize the land use efficiency under the trees, and (3) to investigate the effects of shade by maintaining different distances to *Ziziphus* on forage crops yield and yield.

MATERIALS AND METHODS

Experimentation

To evaluate the Alfalfa *Ziziphus* agroforestry potential for forage production under different nitrogen levels, a field experiment was conducted at the Agricultural Research Station, King Abdulaziz University, at Hada Al-Sham during the 2013 and 2014 seasons. The main plot treatments were three nitrogen rates, N0: Zero nitrogen per hectare was applied, N1: 200 kg nitrogen per hectare was applied, and N2: 400 kg nitrogen per hectare was applied. The half nitrogen rates were applied during the growth period of the 1st cut in 3 equal doses, the first dose added after 20 days from sowing, the second dose after 30 days, and the third after 40 days, then the left of the nitrogen rate was applied during the season, equally after each cut. Sub-plots were occupied with *Ziziphus* tree-forge crops intercropping systems (*Ziziphus* -alfalfa-intercropping and alfalfa-sole). The sub-sub plot treatments were three distances from *Ziziphus* tree. The D1 was 1 cm apart while, D2 was 2 m, and D3 was 4 m apart. Split-split plot design was used with three replications. The experimental plot (sub-sub plot) size was 7 m long and 2 m width, with 20 cm, row spacing in alfalfa Table 1.

Crop Husbandry

Soil preparations were started 1 month before plantation. An area with previously cultivated *Ziziphus* tress was selected and marked for intercropping. A nearby area without *Ziziphus* trees were selected for sole plantation. Land was cultivated with tractor mounted plough followed by planking and leveled. Planting was done at the first week of December 2013. Complex fertilizer of NPK (20:20:20) was applied as basal dose during the soil preparation. Area was divided into main plots for nitrogen application, sub-plot for *Ziziphus* - forage crops intercropping, and sub-sub plots for distance allocation. Surface applied drip irrigation system was installed for irrigation application. Pipes were laid out at 20 cm apart and dripper were 9 cm apart.

Table 1: Agro meteorological data of the growth months

Months	Temperature (°C)		Relative humidity (%)		Rain (mm)
	Minimum	Maximum	Minimum	Maximum	
January	10.32	32.1	100	61.46	0.77
February	13.25	35.9	100	58.28	0
March	14.99	36.9	98.7	56.15	2.73
April	14.4	38.02	96.7	46.97	21.21
May	20.43	44.49	98.6	49.44	0
June	21.03	45.17	95.6	35.88	0
July	23.83	43.85	91.9	46.95	0.07
August	22.92	40.54	94.4	51.52	0
September	22.61	44.74	99.3	50.12	0
October	20.55	42	99.6	55.86	0
November	15.9	36.07	100	55.78	3.5
December	14.04	33.67	99.3	61.61	0

Recorded Data

Ten cuts were harvested throughout the year. The cutting period was approximately 30-45 days. The first cut was harvested after 30 days of plantation. The detail of all cuts is provided here (1st; 01 February 2014; 2nd 15 March 2014; 3rd 15 April 2014; 4th 15 May 2014; 5th 15 June 2014; 6th 15 July 2014; 7th 15 August 2014; 8th 15 September 2014; 9th 15 October 2014; and 10th 15 November 2014).

The following traits were recorded in each cut. Plant height (cm) on 20 random guarded plants/plot was recorded by a measuring scale. Fresh forage yield/ha (t) converted from the 1 m^2 fresh forge weight/plot. Dry forage yield/ha(t)converted from the 1 m^2 dry forge weight/plot.

Statistical Analysis

The obtained data of the experiment were statistically analyzed according to El-Nakhlawy (2010) by calculating the analysis of variance, then the means were separated and statistically compared using the least significant difference test at $P \leq 0.05$ after applying the analysis of variance assumptions.

RESULTS AND DISCUSSION

Plant Height (cm)

Statistical analysis of the plant height data described significant variation with applied levels of main and sub plot factors. The main effect of nitrogen, intercropping, and their interaction was highly significant; however, the effect of distance from *Ziziphus* and two way interaction of distance to nitrogen and intercropping system was mostly insignificant. Three way interaction of nitrogen, intercropping, and distance was highly significant for all cuts (Table 2).

By increasing the nitrogen application, a growth increment was observed but it was non-significant for 200 kg/ha and 400 kg/ha. Intercropping produced higher yield as compared to sole plantation. The distance of 2 m was optimum for alfalfa plantation for almost all cut numbers. For 200 kg N/ha alfalfa intercropping produced higher yield for 1st, 2nd, 7th, and 9th cut number at 2 m distance. For 3rd, 4th, 5th, 6th, and 8th cut number, it was higher for 4m distance. While the 10th cut number produces maximum alfalfa height at 1 m distance. At 400 kg N/ha 1st, 2nd, 5th, 6th, and 8th cut number produced taller plants, whereas rest were superior for 200 kg N/ha.

Fresh Biomass Accumulation (t/ha)

Effect of nitrogen fertilizer, planting distance, and intercropping was significant for fresh biomass accumulation. However, the two way interaction of these two factors was variable and mostly non-significant. Three way interaction was highly significant for fresh biomass accumulation of all cut numbers. Plots where nitrogen fertilizer was applied produced more forage production as compared to control. By increasing the dose of fertilizer from 0 kg N/ha to 400 kg N/ha, pronounced increment was recorded and that was also greater for 400 kg N/ha as compared to 200 kg N/ha. Intercropping of alfalfa with *Ziziphus* produced almost 23% increase in fresh biomass production as compared to sole plantation. The effect of planting distance was also very clear and produced almost 40% higher biomass as compared to 1 m distance.

All cuts produced variable amount of alfalfa forage and the range was 1.01-11.81 t/ha for sole plantation and 2.13-12.51 t/ha for intercropping. Maximum forage production was attained at 400 kg N/ha for intercropping at 2 m planting distance. Cut 1, 3, 6, and 8 produced higher forage yield at 2 m distance for intercropping with 400 kg N/ha, whereas 1 m distance produced maximum forage for cut number 7. At 200 kg N/ha, cut 2, 4, and 9 produced maximum fresh biomass yield at 2 m distance while cut 5 and 10 produced maximum yield at 4 m distance (Table 3).

Dry Biomass Accumulation (t/ha)

Analysis of variance for alfalfa dry biomass accumulation reported significant effect of nitrogen fertilizer, intercropping, and distance. Two way interaction of nitrogen × intercropping and intercropping × distance was also significant. The interaction of nitrogen fertilizer × distance was non-significant. Three way interaction of nitrogen × intercropping × distance was significant for most of the cut numbers.

Table 2: Plant height (cm) of alfalfa forage for 10 consecutive cuts under different levels of nitrogen, intercropping and distance from *Ziziphus* tree

Fertilizer (kg/ha)	Crop	Cut 1	Cut 2	Cut 3	Cut 4	Cut 5	Cut 6	Cut 7	Cut 8	Cut 9	Cut 10
0	Alf-IC										
	1 m	31.33	32.33	44.33	33.66	36.03	41.03	61.66	50.04	51.66	75.33
	2 m	30.02	34.02	33.01	38.33	41.04	36.04	62.66	61.66	63.33	84.66
	4 m	33.66	35.66	32.05	44.66	38.33	37.66	62.33	53.33	66.66	72.33
	Alf-Sol										
	1 m	22.33	22.33	27.06	20.33	26.66	25.66	57.31	51.33	71.33	84.33
	2 m	21.33	21.33	30.00	28.66	33.33	30.05	55.66	41.66	70.41	76.54
	4 m	27.66	28.33	27.66	33.33	33.33	28.33	61.00	44.31	55.66	85.06
200	Alf-IC										
	1 m	40.02	32.33	31.03	40.66	43.33	37.04	70.42	65.33	69.31	85.10
	2 m	40.33	37.33	39.04	49.66	48.66	39.03	68.33	67.33	77.33	80.66
	4 m	40.00	37.03	40.06	55.03	57.10	40.14	67.66	68.33	67.04	80.33
	Alf-Sol										
	1 m	25.01	25.33	24.00	41.33	36.66	35.66	64.66	66.66	71.10	69.12
	2 m	29.03	27.33	30.66	47.07	45.66	39.03	56.66	64.66	75.66	71.66
	4 m	29.00	26.33	22.04	51.01	43.66	37.33	59.33	61.66	72.03	81.33
400	Alf-IC										
	1 m	35.66	35.66	27.66	46.66	59.04	46.20	69.04	70.66	67.33	84.33
	2 m	42.66	36.33	30.33	53.66	60.66	36.33	70.04	71.33	69.66	80.45
	4 m	40.01	37.66	33.33	54.00	58.04	45.66	70.01	68.33	74.14	84.33
	Alf-Sol										
	1 m	38.66	43.66	37.33	41.02	44.33	46.04	62.66	68.66	68.66	76.66
	2 m	44.04	43.33	39.03	51.33	47.33	42.66	68.33	65.04	68.66	87.33
	4 m	46.03	41.66	26.04	47.02	43.33	39.33	68.04	69.33	68.41	85.34
LSD ($P \leq 0.05$)		3.54	4.65	2.54	5.22	4.32	4.90	7.65	4.33	6.75	8.76

LSD: Least significant difference, Alf-IC: Alfalfa-intercropping, Alf-Sol: Alfalfa-sole

The dry biomass accumulation trend was almost similar to fresh biomass accumulation. Dry biomass was higher where 200 kg N/ha was applied as compared to 400 kg N/ha. The effect of intercropping was also significant. Planting distance of 2 m was optimum for continuous sustainable supply of dry forage. All cuts produced dry biomass accumulation of a range of 0.51-6.82 t/ha. The highest biomass was recorded for the interaction of 200 kg N/ha, intercropping, and 1 m distance (Table 4).

Table 3: Fresh biomass (t/ha) of alfalfa forage for 10 consecutive cuts under different levels of nitrogen, intercropping and distance from *Ziziphus* tree

Fertilizer (kg/ha)	Crop	Cut 1	Cut 2	Cut 3	Cut 4	Cut 5	Cut 6	Cut 7	Cut 8	Cut 9	Cut 10
0	Alf-IC										
	1 m	3.80	5.81	5.71	8.10	2.52	2.13	3.16	5.86	4.16	7.93
	2 m	5.10	6.50	6.37	3.43	2.66	2.70	4.43	4.66	3.52	6.86
	4 m	6.86	8.23	7.24	6.01	2.26	2.61	6.23	4.86	3.83	8.16
	Alf-Sol										
	1 m	2.98	2.71	2.51	6.66	0.66	2.03	2.32	5.53	3.83	6.54
	2 m	5.17	3.06	2.82	4.83	1.86	2.26	1.52	5.44	4.43	7.06
	4 m	5.40	3.26	2.71	2.33	1.46	1.01	1.83	5.51	3.66	7.36
200	Alf-IC										
	1 m	7.50	10.36	9.33	9.33	2.96	4.66	6.33	8.73	8.33	10.66
	2 m	8.90	12.33	12.08	11.33	3.12	5.31	7.61	8.10	8.33	11.86
	4 m	9.23	8.93	7.86	7.43	3.43	4.04	6.16	7.23	8.16	12.51
	Alf-Sol										
	1 m	6.16	3.43	3.19	3.22	1.26	2.31	4.56	6.56	4.95	11.11
	2 m	7.90	3.43	3.15	6.21	1.66	2.66	4.16	8.34	6.53	10.23
	4 m	5.66	4.13	3.43	4.33	1.86	3.33	3.55	6.66	6.90	10.16
400	Alf-IC										
	1 m	9.03	8.11	7.29	6.60	3.06	5.66	7.16	7.33	6.83	12.34
	2 m	11.66	12.11	12.34	9.20	3.03	7.12	7.66	9.26	7.83	11.33
	4 m	11.33	7.36	6.48	6.36	3.06	5.51	7.56	7.33	8.03	12.11
	Alf-Sol										
	1 m	7.53	10.33	9.61	7.21	1.73	4.46	3.26	7.13	6.06	10.83
	2 m	11.06	11.66	10.73	10.93	2.33	5.05	3.73	6.66	6.53	11.83
	4 m	11.02	8.04	6.64	5.06	1.86	4.41	4.20	6.84	7.83	9.83
LSD ($P \leq 0.05$)		2.11	3.21	1.78	2.65	2.20	1.98	2.22	1.09	1.93	2.32

LSD: Least significant difference, Alf-IC: Alfalfa-intercropping, Alf-Sol: Alfalfa-sole

Table 4: Dry biomass (t/ha) of alfalfa forage for 10 consecutive cuts under different levels of nitrogen, intercropping and distance from *Ziziphus* tree

Fertilizer (kg/ha)	Crop	Cut 1	Cut 2	Cut 3	Cut 4	Cut 5	Cut 6	Cut 7	Cut 8	Cut 9	Cut 10
0	Alf-IC										
	1 m	1.33	2.51	1.99	2.03	0.87	0.74	1.10	2.46	1.45	2.77
	2 m	2.05	2.83	2.61	2.66	1.09	1.10	1.81	1.49	1.43	2.81
	4 m	2.81	3.33	2.97	3.37	0.92	1.06	2.55	1.84	1.57	3.34
	Alf-Sol										
	1 m	1.31	1.32	1.10	1.18	0.29	0.88	1.01	1.93	1.68	2.86
	2 m	1.75	1.66	0.95	1.04	0.63	0.77	0.51	2.16	1.49	2.40
	4 m	1.78	1.73	0.89	1.07	0.48	0.33	0.60	2.09	1.21	2.43
	Alf-IC										
200	1 m	4.80	3.72	5.71	6.63	1.89	2.98	4.05	3.25	5.33	6.82
	2 m	3.91	4.96	5.97	5.42	1.36	2.22	3.34	3.04	3.66	5.22
	4 m	3.78	3.66	3.22	3.66	1.40	1.64	2.52	2.74	3.03	5.12
	Alf-Sol										
	1 m	2.15	1.63	1.11	1.20	0.44	0.80	1.59	2.75	1.71	3.88
	2 m	3.23	1.30	1.29	1.40	0.68	1.09	1.70	2.56	2.67	4.19
	4 m	2.32	2.10	1.40	1.69	0.76	1.36	1.43	2.53	2.82	4.16
	Alf-IC										
400	1 m	3.96	2.76	3.20	5.56	1.34	2.49	3.15	3.18	3.35	5.28
	2 m	4.96	4.56	4.19	4.28	1.59	2.41	2.60	2.99	2.66	3.85
	4 m	4.74	3.26	2.13	4.43	1.31	1.81	2.49	2.78	2.65	3.99
	Alf-Sol										
	1 m	3.82	5.16	6.15	6.61	1.10	2.85	2.09	2.49	3.88	4.93
	2 m	3.86	4.13	4.72	5.13	1.02	2.23	1.64	2.66	2.87	5.20
	4 m	3.51	3.53	2.72	3.28	0.76	1.80	1.72	2.58	3.21	4.03

Alf-IC: Alfalfa-intercropping, Alf-Sol: Alfalfa-sole

The improved forage growth and biomass accumulation under intercropping as compared to sole plantation may be due to *Ziziphus* plants that may have developed a deep and extensive root system that ensures its ability to exploit deep water sources, thereby maintaining a sufficient water and nutrient supply for prolonged periods when the upper soil layers are drying out. This extra moisture and nutrient supply favored alfalfa growth and nutrient acquisition thus increased plant growth and biomass accumulation. Under ideal environmental conditions, *Ziziphus mauritiana* exhibits very high rates of net photosynthesis and stomatal conductance. Any surplus of assimilated carbohydrates that is not invested in growth is stored as starch in the roots, leading to very high reserves of carbohydrate in the below-ground structures. These resources may be taken up by the companion crop such as forage in agroforestry.

Alfalfa has a deep root that reaches down to 4 m, but can reach 7-9 m in well-drained soils. Numerous studies reported the co-occurrence of tree and grass/crop roots throughout soil profiles (Osborne, 2000). Generally speaking, the lateral spread of roots tends to be concentrated in the canopy area in humid zones, whereas they extend far beyond this area in more arid zones to acquire adequate supplies of soil moisture.

The positive effect of agroforestry interaction is in microclimate, where trees modify microclimatic conditions including temperature, water vapor content, and wind speed (Jose *et al.,* 2004). The resultant effects will be in the form of increased growth rate, soil moisture and soil protection (Tamang *et al.,* 2010). Agroforestry also produce positive net tree effect on availability of nitrogen and assist in capture and use of the underutilized resources from the soil (Ong *et al*., 2002). Under agroforestry system, soil physical properties were maintained similar to soil under natural vegetation (Tamang *et al*., 2014). It also improves water use efficiency by reducing the unproductive components of the water balance (Ong *et al*., 2002), such as soil evaporation loss (Kinama *et al.,* 2007). Previously, positive effect of nitrogen was studied on intercropping for forage production.

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