Effects of Nitrogen Fertilization and inter*Ziziphus Jujube*alleys cropping on blue panic grass (*Panicum antidotale* Retz) yield

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Abstract— *In order to test the effects of intercropping and nitrogen fertilization on blue panic (Panicum antidotale) yield, a field experiment was conducted at the Agricultural Research Station of King Abdulaziz University, located at Hada Al-Sham during two consecutive seasons (2013 and 2014). Blue panic was intercropped between interspaces alleys of Ziziphus Jujube under three different levels of nitrogen fertilizer (0 kg N/ha, 200 kg N/ha and 400 kg N/ha in the form of commercial Urea,46%) and three distances from the jujube tree (1m ,2m and 4m). Blue panic fresh and dry forage yield (tons/ha) and quality was assessed during ten cuttings harvests. The results exhibited significant effects of intercropping, nitrogen fertilization and distance from the tree on forage yield and quality. Forage yield across all ten harvests were higher under intercropped plots compared to sole crops and in plots treated with 200 and 400 kg N and 2-meter distance from the trees. Total fresh forage yield /ha/10 cuts of the intercropped blue panic under 400 kg N/ha and 2m distance reached 186 tons/ha/year. Whereas the highest protein content means overall the different cuts was 11.51% in plots fertilized with 400 kg N/ha at 1m distance from the trees. This current study highlights the importance of utilizing jujube alleys to maximize land use value of this widely planted arid land tree.*

Keywords— Forage yield, Forage quality, Jujube tree, alley cropping.

I. INTRODUCTION

Lack of arable land and shortage of water, in addition to salinity are major problems in arid land agriculture. For sustainable agriculture in these dry lands FAO recommended integration of agroforestry system in arid land farming system (FAO,1993). Alley cropping systems helps in diversifying land income from agriculture cash crops and tree products, improve microclimate and trees provided shelter and source of organic matter. The positive interaction of agroforestry are in the form of modify microclimatic conditions including temperature, water vapour content and wind speed (Jose *et al.,* 2004). This will eventually increase growth development rates (Elfeel et al. 2013). It also, improve soil moisture and soil protection (Tamang *et al.,* 2010). Agroforestry also, produce positive net tree effect on availability of nitrogen (Kho, 2000) and assist in capture and use of the limited unused resources from the soil (Ong *et al.*, 2004; Jackson *et al.,* 2000). Under agroforestry system soil physical properties were maintained similar to soil under natural vegetation (Silva *et al*., 2011). It also, improves water use efficiency (Ong *et al.*, 2002) and reduce soil evaporation loss (Kinama *et al.*,2005). Recently agroforestry proved to be very important elements inclimate change mitigation (Nair *et al*., 2011).

Blue panic is a vigorous, tufted deeply rooted perennial grass that develops from short, thick and somewhat bulbous rhizomes (Surhone *et al.,* 2010). It is mainly used for fodder and grain production. Several cultivars are commercially available (FAO, 2011). Blue panic can yield 10-50 tons of fresh material/ha (El-Nakhlawy *et al.*,2015 and Ecocrop, 2011). Hay yields vary from 2.5 to 6 t DM/ha under rainfed conditions to almost 5 t/ha under irrigation (FAO, 2011).

P. antidotale originated from the Indian subcontinent, Arabian peninsula and Western Asia and is now naturalized in many tropical and subtropical areas (FAO, 2011*).* ***Blue panic***thrives well in saline and alkaline soils and both sandy and black cracking clay soils (El-nakhlawy *et al.*,2015; Partridge, 2003). It responds positively to the addition of N. It is a full sunlight grass but tolerates partial shading and fire resistant (FAO, 2011).

II. MATERIALS AND METHODS

2.1 Location of the experiment

A field experiment was conducted at the Agricultural Research Station, King Abdulaziz University, at Hada Al-Sham during the 2013 and 2014 seasons.

2.2 Experimental Design

Split plot design with three replications was used. The main plot treatments were 3 nitrogen rates (N0: Zero nitrogen per hectare; N1: 200 kg nitrogen per hectare; N2: 400 kg nitrogen per hectare). Half amount of the 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. ,The remaining amount of the nitrogen rate was applied during the season , equally after each cut. Sub plots treatments were occupied with three distances from ziziphus tree (D1: After 1 cm; D2: After 2 m; D3: After 4 m).

2.3 Crop Husbandry

Soil preparations started one month before plantation. An area with previously cultivated ziziphus tress were selected and marked for intercropping. A nearby area without ziziphus trees were selected for sole crop as control. Land was cultivated with tractor-mounted plough followed by planking and leveled. Planting was done at the first 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 and sub plot 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.

2.4 Field crop parameters

Ten cuts were harvested from the blue panic crop when 10% of the plants reached flowering stage. The harvest was done at one-month interval between each cut and another starting from February, 2014 to November, 2014. Fresh Forage yield/ha (t) converted from the 1 m^2fresh forage weight/plot. Dry Forage yield/ha(t) converted from the 1 m^2 dry forage weight/plot.

2.5 Protein content

Crude protein content of plants (%) were determined according to AOAC (2000) by measuring the N (%) by Automatic Kjeldahl instrument and the results were multiply by 6.25

III. RESULTS AND DISCUSSION

3.1 Fresh yield (tons/ha)

The data presented in Tables 1-10 revealed that intercropping system affected the fresh forge yield biomass significantly at (P≥ 0.01) for cuts no 6 ,7and 9, while all other cuts were affected significantly at (P≥ 0.05). The distance of crops from the trees produced significant effect on fresh forge yield at (P≥ 0.01) for cuts no 1.2.3 and 4, whereas all other cuts were affected significantly at (P≥ 0.05). The interaction effect of nitrogen with intercropping system, nitrogen with distance, intercropping system with distance and the interaction of nitrogen, intercropping system and distance were affected the fresh forge yield in all cuts significantly at (P≥ 0.01) .

TABLE 1
MEANS OF BLUE PANIC FRESH AND DRY FORAGE YIELD (TON/HA) AS AFFECTED BY THE INTERACTION BETWEEN THE DIFFERENT RATES OF NITROGEN FERTILIZER, INTERCROPPING SYSTEMS AND DISTANCES FROM THE *ZIZPHUS* TREE FOR THE FIRST CUT

N rate (ton/ha)	Cropping	Fresh yield			Dry yield		
		1m	2 m	4 m	1m	2 m	4 m
0.0	Intercrop	21.13	21	18.8	7.608	4.62	5.64
	Sole crop	10.33	14.66	16.66	5.68	7.18	8.00
200	Intercrop	21.43	24.4	23.33	9.85	10.49	10.03
	Sole crop	13.92	16.58	15.51	5.01	3.64	4.65
400	Intercrop	20.83	21.73	24	10.45	11.64	11.52
	Sole crop	18.16	22.66	22	8.35	9.74	9.46
RLSD(0.05)		0.67			0.28		

TABLE 2
MEANS OF BLUE PANIC FRESH AND DRY FORAGE YIELD (TON/HA) AS AFFECTED BY THE INTERACTION BETWEEN THE DIFFERENT RATES OF NITROGEN FERTILIZER, INTERCROPPING SYSTEMS AND DISTANCES FROM THE *ZIZPHUS* TREE FOR THE SECOND CUT

N rate (ton/ha)	Cropping	Fresh yield			Dry yield		
		1m	2 m	4 m	1m	2 m	4 m
0.0	Intercrop	17	16.33	18.66	8.23	8.06	9.76
	Sole crop	5.73	9.03	8.26	2.93	4.40	4.26
200	Intercrop	19.66	20.63	19.2	9.00	10.33	9.36
	Sole crop	12.33	16.33	14.66	4.76	7.26	6.00
400	Intercrop	18.33	19.66	21.66	6.66	9.66	7.00
	Sole crop	17.66	14.33	16	8.33	7.00	8.66
RLSD(0.05)		0.70			0.39		

TABLE 3
MEANS OF BLUE PANIC FRESH AND DRY FORAGE YIELD (TON/HA) AS AFFECTED BY THE INTERACTION BETWEEN THE DIFFERENT RATES OF NITROGEN FERTILIZER, INTERCROPPING SYSTEMS AND DISTANCES FROM THE *ZIZPHUS* TREE FOR THE THIRD CUT

N rate (ton/ha)	Cropping	Fresh yield			Dry yield		
		1m	2 m	4 m	1m	2 m	4 m
0.0	Intercrop	16.15	14.21	16.61	5.81	3.12	4.98
	Sole crop	5.04	8.67	7.77	2.77	4.24	3.72
200	Intercrop	18.68	17.95	17.08	8.59	7.71	7.34
	Sole crop	10.85	15.68	13.78	3.90	3.44	4.13
400	Intercrop	17.41	17.11	19.28	8.57	9.58	9.37
	Sole crop	15.54	13.76	15.04	7.15	5.91	6.46
RLSD(0.05)		1.07			0.49		

TABLE 4
MEANS OF BLUE PANIC FRESH AND DRY FORAGE YIELD (TON/HA) AS AFFECTED BY THE INTERACTION BETWEEN THE DIFFERENT RATES OF NITROGEN FERTILIZER, INTERCROPPING SYSTEMS AND DISTANCES FROM THE *ZIZPHUS* TREE FOR THE FORTH CUT

N rate (ton/ha)	Cropping	Fresh yield			Dry yield		
		1m	2 m	4 m	1m	2 m	4 m
0.0	Intercrop	20.03	16.1	13.43	6.12	3.59	5.6
	Sole crop	8.8	13.16	9	3.15	4.42	3.96
200	Intercrop	15.66	19.33	18	9.04	8.87	8.25
	Sole crop	10.66	10.66	12	4.44	3.59	4.4
400	Intercrop	24.16	20.83	18.66	10.80	9.63	10.4
	Sole crop	16	16	13.66	8.12	6.16	6.88
RLSD(0.05)		0.91			14.15		

TABLE 5
MEANS OF BLUE PANIC FRESH AND DRY FORAGE YIELD (TON/HA) AS AFFECTED BY THE INTERACTION BETWEEN THE DIFFERENT RATES OF NITROGEN FERTILIZER, INTERCROPPING SYSTEMS AND DISTANCES FROM THE *ZIZPHUS* TREE FOR THE FIFTH CUT

N rate (ton/ha)	Cropping	Fresh yield			Dry yield		
		1m	2 m	4 m	1m	2 m	4 m
0.0	Intercrop	10.46	7.13	6.46	3.76	1.56	1.94
	Sole crop	4.03	4.53	3.66	2.21	2.22	1.76
200	Intercrop	13.66	14.76	13.06	6.28	6.34	5.61
	Sole crop	5.96	6.2	5.83	2.14	1.36	1.75
400	Intercrop	12.96	14.2	12.86	7.13	6.95	6.17
	Sole crop	7.7	6.16	6.83	3.54	2.65	2.93
RLSD(0.05)		0.44			0.37		

TABLE 6
MEANS OF BLUE PANIC FRESH AND DRY FORAGE YIELD (TON/HA) AS AFFECTED BY THE INTERACTION BETWEEN THE DIFFERENT RATES OF NITROGEN FERTILIZER, INTERCROPPING SYSTEMS AND DISTANCES FROM THE *ZIZPHUS* TREE FOR THE SIXTH CUT

N rate (ton/ha)	Cropping	Fresh yield			Dry yield		
		1m	2 m	4 m	1m	2 m	4 m
0.0	Intercrop	18.53	20.26	22.00	6.67	4.45	6.6
	Sole crop	10.00	22.66	17.00	5.5	11.10	8.16
200	Intercrop	20.00	22.33	24.33	11.96	9.60	10.46
	Sole crop	13.33	16.16	15.33	4.8	3.55	1.6
400	Intercrop	21.26	24.15	26.66	18.15	15.02	12.8
	Sole crop	22.00	20.4	15.16	10.12	8.77	6.52
RLSD(0.05)		0.76			0.61		

TABLE 7
MEANS OF BLUE PANIC FRESH AND DRY FORAGE YIELD (TON/HA) AS AFFECTED BY THE INTERACTION BETWEEN THE DIFFERENT RATES OF NITROGEN FERTILIZER, INTERCROPPING SYSTEMS AND DISTANCES FROM THE *ZIZPHUS* TREE FOR THE SEVENTH CUT

N rate (ton/ha)	Cropping	Fresh yield			Dry yield		
		1m	2 m	4 m	1m	2 m	4 m
0.0	Intercrop	17.86	18.13	20	6.43	3.98	6
	Sole crop	5.13	5.16	6.56	2.82	2.53	3.15
200	Intercrop	19.66	21.66	20.16	9.04	9.31	10.82
	Sole crop	13.66	15.4	21.5	4.92	3.38	6.45
400	Intercrop	20.63	22.33	21.06	13.38	9.96	10.59
	Sole crop	14	17.33	18.33	6.44	7.45	7.88
RLSD(0.05)		0.99			0.49		

TABLE 8

MEANS OF BLUE PANIC FRESH AND DRY FORAGE YIELD (TON/HA) AS AFFECTED BY THE INTERACTION BETWEEN THE DIFFERENT RATES OF NITROGEN FERTILIZER, INTERCROPPING SYSTEMS AND DISTANCES FROM THE *ZIZPHUS* TREE FOR THE EIGHTH CUT

N rate (ton/ha)	Cropping	Fresh yield			Dry yield		
		1m	2 m	4 m	1m	2 m	4 m
0.0	Intercrop	5	4.33	7.33	2.3	1.95	3.74
	Sole crop	4.66	6.2	6.8	2.1	3.16	3.4
200	Intercrop	8.8	9.2	10.86	4.4	3.68	4.99
	Sole crop	8.86	7.86	8.4	3.54	3.61	3.78
400	Intercrop	7.66	13.66	10.5	6.97	6.07	5.25
	Sole crop	6.33	7	7.06	3.23	3.5	2.82
RLSD(0.05)		0.45			0.40		

TABLE 9

MEANS OF BLUE PANIC FRESH AND DRY FORAGE YIELD (TON/HA) AS AFFECTED BY THE INTERACTION BETWEEN THE DIFFERENT RATES OF NITROGEN FERTILIZER, INTERCROPPING SYSTEMS AND DISTANCES FROM THE *ZIZPHUS* TREE FOR THE NINTH CUT

N rate (ton/ha)	Cropping	Fresh yield			Dry yield		
		1m	2 m	4 m	1m	2 m	4 m
0.0	Intercrop	6.66	7.53	7.80	2.4	1.65	2.34
	Sole crop	8.00	10.66	8.33	4.4	5.22	4
200	Intercrop	10.00	10.36	10.31	4.6	4.45	4.45
	Sole crop	7.16	9.50	8.56	2.58	2.09	2.57
400	Intercrop	10.06	11.40	11.16	6.08	5.58	5.36
	Sole crop	9.33	10.16	10.5	4.29	4.37	4.51
RLSD(0.05)		0.30			0.26		

TABLE 10

MEANS OF BLUE PANIC FRESH AND DRY FORAGE YIELD (TON/HA) AS AFFECTED BY THE INTERACTION BETWEEN THE DIFFERENT RATES OF NITROGEN FERTILIZER, INTERCROPPING SYSTEMS AND DISTANCES FROM THE *ZIZPHUS* TREE FOR THE TENTH CUT

N rate (ton/ha)	Cropping	Fresh yield			Dry yield		
		1m	2 m	4 m	1m	2 m	4 m
0.0	Intercrop	13.16	13.33	13.00	4.74	2.93	3.90
	Sole crop	9.53	12.33	11.00	5.24	6.04	5.28
200	Intercrop	14.83	16.00	19.56	6.82	6.88	8.41
	Sole crop	17.00	22.66	18.00	6.12	4.98	5.40
400	Intercrop	15.66	21.33	15.00	10.45	9.85	9.20
	Sole crop	16.56	18.00	18.66	7.62	7.74	8.02
RLSD(0.05)		1.02			0.46		

Fresh forge yield was significantly higher in the intercropping than the sole crop plots under any nitrogen rate or any distance. These results indicated the positive effect of the intercropping in enriching soil nutrients by the zizphus residue (leaves) during the growing seasons (Batish *et al.,* 2007, Jose *et al.,* 2004, Kho, 2000) or due to net effects of the trees on the intercropping system (Ong *et al.,* 2002 and Tomlinson *et al.,* 1995). The trees of *ziziphus* in the intercropping systems modified microclimatic conditions including temperature, water vapour and wind speed that positively affected the forage crops yield (Jose *et al.,* 2004 and Jackson *et al.,* 2000). Also, in most harvest (Table 1 – 10) application of N at rate of both 200 and 400 kg/ha obtained higher yield, whereas in most harvests spacing of 2 meters distance from the tree produced higher yields. This may indicates that the closer the distance from the trees the higher the competition, where far away from the tree will reduced the positive integration between trees and the crops. However, the area of 2-4 meters from the trees had a best complementary interaction between the crop and the trees.

3.2 Dry Yield (tons/ha)

The statistical comparisons using RLSD at $p \geq 0.05$ showed that the dry forge yield /ha significantly increased under the intercropping system at 2m distance and plots fertilized with 200 and 400 kg N/ha compared to the other treatments. The dry forage yield /ha under the effect of the three factors and interactions of different levels of nitrogen fertilizer, intercropping system and distance from ziziphus tree revealed significant results in all harvests.

These findings highlights the positive effects of the intercropping between the ziziphus trees and forage crops in dry forage crops yield especially under the highest nitrogen rate and the middle distance from the trees. The positive effects might been due to the positive effects of the highest nitrogen rate interacted with the highest organic matter near the tree which increase the growth rate and foliage yield of the forage crops that reflected in increased dry forage yield/ha. The increase in the yield under intercropping compared to sole crop may be due to the effects of the tree in microclimatic conditions or soil amendment. These findings are in agreement with the results obtained by (Jose et al., 2004, Tamang et al., 2010, Ong et al., 2002 and Kho, 2000).

Generally by comparing total fresh and dry forage yield/10 cuts under the intercropping and sole crop, the results reflects that the highest forage yield/ha was produced in the intercropped plots that were added with 400 kg N/ha fertilization rate and plants grown at 2m distance from ziziphus trees. Total fresh forage yield /ha/year of the intercropped under 400 kg N/ha and 2m distance were186.4 t/ha (Table 11). Whereas the highest total dry forage yield /ha/year production (93.94 t/ha) was reached in intercropped plots that were added 400 kg N/ha.

3.3 Protein content

Means of protein content overall the cuts of the studied treatments (Table 12) showed that the highest protein contents of the blue panic forage crop was found in the intercropped treatments under 400 kg N/ha and 1m distance from the *ziziphus* trees. The highest protein contents of the last treatments was 11.51% from the intercropped blue panic. Although the results in general showed that blue panic contains little protein contents, but addition of N significantly increased the protein levels in the forage. While a combination of both intercropping and N addition increased further protein content. Unlike, forage yield protein content was higher in plants grown at distance of 1 from the trees. The increase in the protein in this distance may explained by the mutual effects of added inorganic N and protein produced by decomposition of organic matter. Where the low forage yield compared to 2 meter distance may be due to higher above and below ground competition between the trees and the crops.

TABLE 11
TOTAL FRESH AND DRY FORAGE YIELD (TON/HA/YR) OF BLUE PANIC AS AFFECTED BY THE INTERACTION BETWEEN THE DIFFERENT RATES OF NITROGEN FERTILIZER, INTERCROPPING SYSTEMS AND DISTANCES FROM THE ZIZPHUS TREE

N rate (ton/ha)	Cropping	Fresh yield			Dry yield		
		1m	2 m	4 m	1m	2 m	4 m
0.0	Intercrop	144.09	138.35	144.09	54.06	35.91	50.5
	Sole crop	95.04	107.06	95.04	36.8	50.51	45.69
200	Intercrop	175.89	176.62	175.89	79.58	77.66	79.72
	Sole crop	133.57	137.03	133.57	42.21	36.9	40.73
400	Intercrop	180.84	186.4	181.84	98.64	93.94	87.66
	Sole crop	143.24	145.8	143.24	67.19	63.29	64.14
RLSD(0.05)		1.02			1.02		

TABLE 12
MEANS OF PROTEIN CONTENTS (%) OVERALL THE TEN CUTS OF BLUE PANIC UNDER THE INTERACTION BETWEEN NITROGEN FERTILIZER RATES, INTERCROPPING SYSTEMS AND DISTANCES FROM *ZIZIPHUS* TREE

N rate (ton/ha)	Cropping	Distance		
		1m	2 m	4 m
0.0	Intercrop	9.634	9.1	9.0
	Sole crop	7.498	9.5	9.7
200	Intercrop	10.196	9.8	9.7
	Sole crop	9.57	9.9	10.7
400	Intercrop	11.51	11.1	10.9
	Sole crop	9.498	10.8	10.4
RLSD(0.05)		0.78		

IV. CONCLUSION

The current study revealed that planting interspaces alleys of *Jujube* trees grown under arid saline soil will increase blue panic forage yield compared to sole cropping. The distance from the tree also, has impact in forage production.

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REFERENCES

[1] Ecocrop, 2011. Ecocrop database. FAO, of the United Nation, Rome, Italy, accessed Novemeber, 2015.

[2] Elfeel AA , Bakhashwain AS and Abohassan RA 2013. Interspecific interactions and productivity of Leucaena leicocephala and Clitoria ternatea under arid land mixed cropping. The Journal of Animal and Plant Sciences (the JAPS), 23(5): 1424 – 1430.

[3] El-Nakhlawy, F.S.,Ismail,S. and Basahi,J.2015. Forge Yield and water use of Alfalfa (Medicago Sativa L.) and Blue Panic (Panicum antidotale Retz.) irrigated with saline water in surface and subsurface drip irrigation systems. Wulfenia 22(2):110-123.

[4] **El-Nakhlawy, F.S. 2010.** Experimental Design and Analysis in Scientific Research. Sci. Pub. Center, King Abdul Aziz University, Saudi Arabia.

[5] FAO (2011). Grassland Index. A searchable catalogue of grass and forage legumes. FAO.

[6] FAO 1993. Key aspects of strategies for the sustainable development of dry lands. FAO, Rome, Italy.

[7] Jackson N.A., J.S. Wallacea and C.K. Ong 2002. Tree pruning as a means of controlling water use in an agroforestry system in Kenya. Forest Ecology and Management. 126: 133 – 148.

[8] Jose, S., A.R. Gillespie, and S.G. Pallardy 2004. Interspecific interactions in temperate agroforestry. Agroforestry Systems, 61: 237-255.

[9] Kho, R.M. 2000. A general tree-environment-crop interaction equation for predictive understanding of agroforestry system. Agriculture, Ecosystem and Environment. 80: 87 – 100.

[10] Kinama, J.M., C.J. Stigter, C.K. Ong, J.K. Na'ang and F.N. Gichuki 2005. Evaporation from soil below sparse crops in contour hedge row agroforestry in semi arid Kenya. Agriculture and Forest Meteorology. 130: 149 – 162.

[11] Nair, P. K. 2011. Agroforestry systems and environmental quality: introduction. Journal of environmental quality, 40(3): 784-790.

[12] Ong KC, Kho RM and Radersma S 2004. Ecological interactions in multispecies agroecosystems: Concepts and rules. In Van Noordwijk M, Cadisch G and Ong CK(eds) (2004). Belwo ground interactions in tropical agroecosystems: Concepts and models with multiple plant components. CABI publishing, CAB International.

[13] Ong, C.K., J. Wilson, J.D. Deansb, J. Mulaytac, T. Raussena and N. Wajja-Musukwed 2002. Tree–crop interactions: manipulation of water use and root function. Agricultural Water Management. 53: 171–186.

[14] SAS Institute Inc. 2000.SAS Statistical analysis, Version 8, SAS institute Inc., Cary, NC 27513, USA.

[15] **Silva GL , Lima HV , Campanha MM , Gilkes RJ , Oliveira TS 2011**. Soil physical quality of Luvisols under agroforestry, natural vegetation and conventional crop management systems in the Brazilian semi-arid region. Geoderma 167-168: 61–70.

[16] Tamang, B., M.G. Andreu, and D.L. 2010. Rockwood, Microclimate patterns on the leeside of single-row tree windbreaks during different weather conditions in Florida farms: implications for improved crop production. Agroforestry Systems.