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Intercropping of Barley (*Hordeum vulgare*) with *Grewia tenax* as Winter Forage Production in Saline soils of Khartoum State of Sudan

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Abstract

Barley (*Hordeum vulgare*) was intercropped with *Grewia tenax* under irrigation regimes in saline soils of dry land in Sudan. That aimed to find out suitable agroforestry system to suit saline soil in Khartoum State as well as to investigate effect of tree spacing on barley yield production as winter forage crop. Thus *G.tenax* tree species was spaced at 4x4m besides barley crop that sown at 2 levels at 1m (GS1) and 1.5m (GS2) apart from tree trunks in two seasons of 2018 and 2019. Parameters that measured for *G.tenax* its growth and fruit yield per tree. While for barley crop were; plant height, number of plant and forage yield as fresh and air dry per ha as well as land equivalent ratio. Besides soil chemical properties under intercropped plots, sole *G.tenax* trees and open areas as control at 0-30 cm and 30-60 cm depths. The results revealed that trees growth did not differ in first season 2018. Whereas significant differences were recorded in 2019; when compared GS2 with GS1 and control in tree height. Likewise for tree collar and crown diameters under GS2. Barley plant height was higher under sole cropping in 2018. Likewise for barley biomass dry weight under intercropping and *G.tenax* fruit under sole trees. Land equivalent ratio (LER) was higher under GS2. Soil fertility in terms of NPK and Mg was higher under intercropped plots at upper layer 0-30 cm. whereas OC was higher at lower layer (30-60 cm) for intercropped plots. Soluble Cations were higher under lower at 30-30 cm depth for Ca and Na , similarly for pH, CaCo3, EC, SAR and C/N .Therefore, intercropping of barley crop as winter forage with *G.tenax* is feasible to maintain food security, halts desertification and sink carbon in dry lands.

Key words: Agroforestry, intercropping, *Grewia tenax*, barley, saline soils, LER.

1-Introduction

Agroforestry is a land use system that incorporates deliberately integration of forests into agricultural lands. Therefore, it aims to manage the natural resources in a sustained manner that provides productivity and protection means for lands for the benefit of human and animals (Baumer, 1986). Thereby, some agroforestry systems would diversify, maintain and improve some existing farming systems (Lundgren, 1983; Raintree, 1984; Julius *et al*.2017)).In this respect, growing crops between trees is widely existed and considered an old agro forestry practice in many African and Asian countries. Hence, trees' characteristic, density and spatial arrangements are the main factors in succeeding this agro forestry system. However, this considered as a signs of sustainability and productivity of this agro forestry system or practice (Nair, 1993). Besides that appropriate agro forestry systems depend on the degree of competition between trees and crops. Thus trees generally can compensate soils by improving its physical characteristics through ameliorating the physical properties by penetrating trees roots into deep soil layers (Hussein *et al*., 1998; Lassailly, 1984). Also trees can improve soil fertility in terms of Nitrogen, Phosphorus and Organic carbon. In this respect, using of multi- purpose trees such as nitrogen fixing trees will improve or increase soil fertility (Young, 2001; Nasre Aldin *et al*., 2010).Besides that introducing of some other multi-purpose trees in marginalized soils such as saline soils will maintain or increase their efficiency in terms of productivity and sustainability (Vanderbilt, 1990).Despite that agro forestry systems or practices in terms of intercropping or alley cropping are well recognized and widely spread. Thus trees and crops were intercropped sequentially or intimately in many continents. Therefore farmers will diversify their crops by getting multiple products from these practices. These products would be provided from the trees in terms of timber, fruits, fodder and gum or from the crops in terms of grain yielder biomass. Therefore, farmers can safeguard their cropping systems by having these multiple products within different time during the cropping seasons (Miehe, 1986, Nasre Aldin *et al*., 2011,). Moreover, farmers can avoid discrepancies with regard to crops failure or other environmental factors. Since other disadvantages can be observed from intercropping in terms of above and below ground competitions.

These can be occurred or manifested in the available resources in terms of light interception, nutrients and water uptakes as well as allopathic effects (Ong *et al*.,1996). In addition to pests and diseases infestations that can be observed due to existence of trees in farms.

Barley (*Hordeum vulgare*) belongs to gramineae family. It is considered as one of the food security crops. And it regarded as the fourth crop world widely after wheat, rice and maize in terms of area size and production. Barley has multiple uses for human and animal, since it used as food and fodder for human and animals respectively. However, barley can be used as green or dry fodder, when it dried it can be mixed with other elements (Ahmed *et al*., 2006; Khair*et al*., 2001). Barley is growing in winter and it tolerates salinity and it considers as drought resistant crop (Arnon, 1972; Wright, 1976; Epsten *et al*., 1980).In this regard, when barley grown as a fodder, it will be harvested in 70 days. While for grain yield, barley can be harvested after 3 months. Barley is rich with carbohydrate and protein contents and it has little fiber content (Hutchinson, 1974; Hamada *et al*., 2017; Morales *et al*., 2009).

Therefore, introduction of this agro forestry system in terms of intercropping of multi- purpose trees with promising field crop, in the saline soils will increase the potentiality of these soils to be productive .Moreover it will diversify farmer income, maintains his food security, halts desertification and sequesters carbon. The objectives of this experiment were to find out an agro forestry model that suits saline soils of Khartoum State, to investigate the effect of trees spacing on some fodder crops in saline soils as well as to find winter fodder withstands less water requirements. .

2. Materials and Methods

2.1. Site description

This experiment was conducted in Forestry and Gum Arabic Research Centre Farm in Soba, Khartoum State, Sudan (Latitude 15º 30′ N; Longitude 30º 30′ E) in Saline soils during the period of July 2018 to 2019. The soil in the site was known as Elbageer soil series; and classified as SodicHaplocombids. The parent materials is Blue Nile Alluvial, the drainage is moderately well drained, moisture conditions is below 10 cm, while ground water is very deep.

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The general soil profile in the experimental site is deep flat, moderately well drained, with dark brown, over very grayish brown soil colour. The soil texture is clay loam, over clayey, moderate medium and fine sub angular blocky structure. The soil is of weak coarse, medium and fine sub angular blocky structure over massive moderately to strongly calcareous soil matrix. And soil pH is alkaline ranged between, 7.6 and 8.6 as indicated in Tables 1 and 2.

Table 1: Soil chemical properties in the experiment site in Soba in 2017.

Depth	EC	$CaCO_3$	SAR	ESP	pH paste	N	O.C	C/N
cm	ds/m	%				%	%	Ratio
0-30	2.1	1.95	9.5	10.5	7.9	0.8	0.49	6
30 – 60	2.5	2.3	10	11	8.4	0.83	0.49	6
60 -100	16.1	5.2	30	30	9.1	0.82	0.49	6

EC (Exchangeable Conductivity), N (Nitrogen Content) and O.C (Organic Carbon), SAR (Sodium Absorption Ratio, ESP (Exchangeable Sodium Percentage).

Table 2: Soil chemical properties in the experiment site in 2017 in Soba.

Depth	Soluble Cations			Soluble Anions		Excl. cal		Available P	CEC
cm	Na	Ca	Mg	CL	HCO_3	Na	K	ppm	
0-30	13.15	9.15	1.95	10.7	1.2	11.4	0.525	2.2	35.5
30 –60	17.3	10.6	2.3	13.1	1.3	19.5	0.61	3.4	39
60- 100	75.2	12.4	3.1	130.1	3.1	128.1	0.72	1.5	45

CEC (Cation Exchange Capacity)

The area is of semi -arid region of low rainfall amounts. The vegetation of the site is local trees species such as Hegleg (*Balanites aegyptiaca*), Tundub (*Capparis decidua*) and mesquite (*Prosopis chilensis*) as stated by Farah (2017).

2.2. Experimental Farm

The experiment was located in a protected area that fenced with barbed wire and connected with perennial water supply. *Grewia tenax* trees of one year old that spaced at 4x4 m were intercropped with barley crop (*Hordeum vulgare*) in a complete randomized block design with 3 replications. The barley crop was broadcasted at one and 1.5 metres apart from *G.tenax* tree trunk in two consecutive seasons of 2018 and 2019 in January. Thus the intercropped plots contained 3 and 2 rows of barley between the *G.tenax* trees for 1 and 1.5 m treatments respectively. Control plots for *G.tenax* trees and barley crop were also used accordingly. The experiment was watered once a week during the growing seasons. Routine cultural practices were carried out for both the crop and the trees as necessary. The experiment plot size was 12x8 m and it has 12 trees of *G.tenax* trees. Therefore, the total experiment area was 225*150 square metre and the total *G.tenax* trees per ha are1250 trees.

*2.3. Grewia tenax T*ree Parameters

Grewia tenax trees were measured in terms of tree height in cm, tree collar diameter in mm, tree canopy diameter in m. *G.tenax* tree fruit yield per tree (gram) was estimated for first and second seasons at ages of one and two years old in March.

2.4. Barley crop Parameters

Barley crop was measured in terms of plant height in cm, number of plant per ha, crop biomass weight as fresh and air dried weight in kg/ha.

2.5. Land Equivalent Ratio (LER)

Land Equivalent Ratio (LER) in terms of crop yield and fruit yield was calculated according to Sullivan (1996). Where the sum fractions of crop yields on the intercrops relative to their mono-crops yield provides a measure of the overall effectiveness of the mixed systems. Therefore, the system is expressed in terms of LER= Xi/Xs+Yi/Ys, where Xs and Ys are the components of yield in either an intercrop where; (I) and (s) are the mono- crops system. In this respect, if LER is more than one that means intercropping is advantageous and vice versa when is less than one (Sullivan, 1998; Raddad and Luukkanen, 2007; NasreAldin *et al*., 2011).

2.6. Soil chemical analysis

Soil samples were taken by Auger from the following places; under the intercropped *Grewia tenax* trees canopy, sole *G.tenax* trees canopy and in the open areas at two depths; 0-30 cm and 30-60 cm to determine soil chemical properties in terms of Nitrogen, Phosphorus, Potassium and Organic Carbon as well as pH, Na, Mg, CaCo3, EC, SAR and C/Nat the end of the second season in 2020. The samples were taken to Soil and Water Centre of Agricultural Research Corporation in Wad Medani and were analyzed .

Statistical analysis of the generated data was done by using GENSTAT Software. The differences between the treatments means of the ANOVAs Tables were determined by using LSD (Least Significant Differences at 5% or 1% levels).

3. Results

3.1. Grewia tenax Growth Measurement

Grewia tenax tree measurements in terms of tree height, tree collar diameter and tree canopy diameter did not differ significantly with respect to distance from the tree trunk either as intercropped with barley crop or as sole trees in the first season 2018 as indicated in table 3.

While *Grewia tenax* trees fruit yield was higher in the intercropped plots particularly under GS2 (1.5 m) when compared with the sole tree treatments as indicated in table 3.

Table 3: *Grewia tenax* tree height cm, collar diameter mm, canopy diameter m and fruit yield in gram under the agro forestry system in seasons 2018 and 2019.

Treatments	Tree height in cm	Tree collar diameter in mm	Tree canopy diameter in m	Tree fruit yield g/tree
Season 2018				
GSI	185.4±17.03a	10.7±3.69a	6.27±2.20a	156.6
GS2	171.3±17.03a	11.1±3.69a	5.83±2.20a	322.6
G	167.9±17.03a	9.5±3.69a	4.87±2.20a	91.4
CV%	12	35.0	48	
LSD	37.95	8.22	4.91	
Season 2019				

GSI	264.9±14.87ab	20.4±2.95a	8.44±0.633ab	515
GS2	274.5±14.87ab	23.13±2.95a	8.68±0.633ab	691
G	231.6±14.87a	20.39±2.95a	6.55±0.633a	817
CV%	10.7	14	11.6	
LSD	46.86	6.86	1.41	

Means followed by the same letters are not significantly different at 5% or 1% level. Key Legend: G=*Grewia tenax*, S1= barley crop cultivated one metre from tree trunk.S2=barley crop cultivated 1.5 metre from tree trunk.

Meanwhile in the second season 2019, *Grewia tenax* tree height was significant at 5% level. Thus it increased by 9.5 cm and 43.4 cm when compared GS2 with GS1 and control respectively. While GS1 increased by 34 cm when compared with control as indicated in table 3.

G.tenax tree collar diameter did not show any significant differences with respect to distance from tree trunk either under intercropping or as control in the second season 2019 as indicated in table 3.While *G.tenax* tree crown diameter was showed minor increase between GS2 and GS1 that amounted to 0.2 m as shown in table 3.

G.tenax tree fruit yield was higher under control trees than in the intercropped ones. Thus it increased by 302 gram and 126 gram when compared control plot with GS1 and GS2 treatments respectively. And it amounted to 1176 gram when compared GS2 with GS1 as shown in table 3.

3.2. Barley crop parameters

In the first season 2018, barley plant height was highly significant at (1% level), under sole barley crop when compared with intercropped treatments as shown in table 4.Similarly barley biomass dry weight was significant at (P< 0.05 level) under the intercropped plots when compared with sole barley crop. However, it showed increase by 88% and 80% for GS2 and GS21 when compared with sole barley crop as indicated in table 4.Whereas no significant differences were recorded for the barley number of plant per ha and biomass fresh weight with respect to spacing from the tree trunk as indicated in table 4.

Table 4: Barley plant height cm, number of plant/ha, biomass fresh weight kg/ha and biomass dry weight kg/ha in the seasons 2018and 2019.

Treatments	Plant height cm	No. of plant/ ha	Biomass fresh weight kg/ha	Biomass dry weight kg/ha

Season 2018				
GSI	12.2±5.05a	2702267±1160965.4a	11600±4105.2a	5322±781.1a
GS2	12.3±5.05a	3716400±1160965.4a	10957±4105.2a	5558±781.1a
Control	51.8±5.05b	2202800±1160965.4a	7270±4105.2a	2959±781.1c
CV%	30.4	54.7	20	20.2
LSD	11.65	2677189.5	4105.2	1801.3
Season 2019				
GSI	41.2±3.48a	4138667±766254.8a	3348±598.6a	1896±277.2a
GS2	40.0±3.48a	3422667±766254.8a	3167±598.6a	1740±277.2a
Control	36.7±3.48a	3832000±766254.8a	1840±598.6a	1611±277.2a
CV%	15.0	39.6	36.8	29.3
LSD	11.35	2498895.3	1952.2	904.1

Means followed by the same letters are not significantly different at 5% or 1% level. G=Grewia tenax, S1= barley crop cultivated one metre from tree trunk.S2=barley crop cultivated 1.5 metre from tree trunk.

In the second season 2019, no significant differences were recorded for the barley crop parameters in terms of plant height, number of plant per ha and fresh and dry biomass weights per ha as with respect to distance from the *G.tenax* tree trunk as indicated in table 4.

3.3. Land Equivalent Ratio (LER)

In the first season 2018, land equivalent ratio was advantageous for the *Grewia tenax* tree with barley crop regardless distance from the tree trunk. But it showed higher LER value under GS2as indicated in table 5. In the second season 2019, LERwas advantageous for *G.tenax* and it has minor difference for the two treatments GS1 and GS2 as indicated in table 5.

Table 5: Land equivalent ratio for intercropping of barley crop with *Grewia tenax* seasons 2018 and 2019.

Treatment	Intercropped barley fresh weight kg/ha	Intercropped trees fruit yield kg/ha	LER
Season 2018			
GS1	11600	156.6	5.6
GS2	10957	322.6	7.2
Sole barley	2959		
Sole *Grewia tenax*		91.4	
Season 2019			

GS1	3348	644.3	2.5
GS2	3167	863.6	2.6
Sole barley	1840		
Sole *Grewia tenax*		1021.0	

Key Legend: G=*Grewia tenax*, S1= barley crop cultivated one metre from tree trunk.S2=barley crop cultivated 1.5 metre from tree trunk.

3.4. Soil Chemical Analysis

Soil pH was higher in the open areas at 30-60 cm than the other areas. While Ca was higher at the 30-60 cm and lower at intercropped plots and open areas at 0-30 cm. K almost has the same value but it was higher in the open areas. Na almost has the same values but lower at 30-60 cm for open areas.Mg almost is same under the *G.tenax* trees but higher at open areas particularly at 30-60 cm as indicated in table 6.

Table 6: Soil chemical properties under intercropped and sole trees and open areas in experiment site in 2020.

Soil depths	Treatments	PH	Ca	K	Na	Mg
0-30	GS1	7.93	7.00	0.37	3.73	1.83
30-60	GS2	8.0	12.67	0.35	3.63	1.33
0-30	G1	7.97	9.83	0.36	3.68	1.58
30-60	GS	7.98	11.25	0.35	3.66	1.46
0-30	C1	7.97	5.50	0.42	3.46	2.77
30-60	C2	11.85	15.25	0.44	1.78	4.00

GS1 and GS2 =intercropped plots *Grewia tenax* with barley, G1&G2= Sole *Grewia tenax* plots, C1 &C2 = Open areas and O.C=Organic Carbon.

Table 6: Soil chemical properties under intercropped and sole trees and open areas in experiment site in 2020.

Soil depths	Treatments	PH	Ca	K	Na	Mg
0-30	GS1	7.93	7.00	0.37	3.73	1.83
30-60	GS2	8.0	12.67	0.35	3.63	1.33
0-30	G1	7.97	9.83	0.36	3.68	1.58
30-60	GS	7.98	11.25	0.35	3.66	1.46
0-30	C1	7.97	5.50	0.42	3.46	2.77

30-60	C2	11.85	15.25	0.44	1.78	4.00

GS1 and GS2 =intercropped plots *Grewia tenax* with barley, G1&G2= Sole *Grewia tenax* plots, C1 &C2 = Open areas and O.C=Organic Carbon.

Nitrogen was higher in open areas particularly at 30-60 cm than in the intercropped plots and sole trees. Organic Carbon was higher under intercropped plots at 30-60 cm than in the other areas and it lower at 30-60 cm in the open areas. Phosphorus was higher in 0-30 cm in the intercropped plots than in the other areas.CaCo3was lower at 0-30 cm in the intercropped plots than in the other areas. And it was very higher at open areas at 30-60cm. EC was almost has the same value except for 30-60 cm in the open areas. SAR was lower at 0-30 cm in the intercropped plots, C/N was higher under 30-60 cm in the intercropped plots as indicated in table 7.

Table 7: Soil chemical properties under intercropped and sole *Grewia tenax* and open areas in experiment site in 2020.

Soil depth cm	Treatments	N	OC	P	CaCo3	EC	SAR	C/N
0-30	GS1	0.07	0.48	3.07	5.2	1.23	1.67	6.33
30-60	GS2	0.06	0.50	2.27	7.07	1.73	2.33	7.67
0-30	G1	0.06	0.49	2.67	6.13	1.48	2.0	7.0
30-60	GS	0.06	0.49	2.47	6.6	1.61	2.17	7.33
0-30	C1	0.07	0.46	2.60	7.73	1.23	2.00	6.70
30-60	C2	0.10	0.38	2.30	8.8	2.75	3.50	4.00

GS1 and GS2 =intercropped plots G*rewia tenax* with barley, G1&G2= Sole *Grewia tenax* plots, C1 &C2 = Open areas, O.C=Organic Carbon.

5. Discussion

In this study*Grewia tenax* tree parameters in terms of tree height, tree collar diameter and tree crown diameter did not differ in the early stage when intercropped with barley crop due to minor competition between trees with crop at this level. Similar results were obtained by Raddad and Luukkanen (2007) when working in *Acacia senegal* intercropped with field crop in Blue Nile of Sudan. While the differences in tree fruit yield in the first season might be due to good site conditions under intercropping than in sole trees. Whereas the increase of fruit under sole *G.tenax* than intercropped ones in the second season 2019, might be due to effect of competition under intercropping site. While the significance in the *G.tenax* tree height in the second season 2019, was probably due to consistent watering for the intercropping plots than in the sole ones. As well as to the well ploughing under intercropping plots by hoes thus been more favourable. Therefore, *G.tenax* tree roots were able to penetrate deeply in the soil and leach soil salinity upward as well. While under sole *Grewia tenax* trees plots the areas around tree trunks were hoed and watered only. For *G. tenax* tree collar diameter the competition was occurred in the narrow spacing, might be due to good site condition as well as to *G.tenax* phonology because is shrubby and has shallow root system. While the significance in *Grewia tenax* tree crown diameter was attributed to the favourable site conditions under intercropped plots than in the sole trees as mentioned above, besides tree phonology and characteristics as well. Meanwhile Raddad and Luukkanen (2013) reported that agricultural management practices can benefit the growth rate of trees under clay soil. But however, with consistent watering and good cultural practices such as ploughing and weeding soil salinity will be leached up from the deep soil layers. This in alignment with Bosshard (1966), he reported that under saline soil of Khartoum Belt salts came up with watering of the site. On the other hand, the competition for below ground resources should be minor under this agro forestry system, since adequate watering is available for the site. Nonetheless, the*Grewia tenax* tree is drought resistant and can tolerate salinity as stated by (Baumer, 1983; Vgot, 1996).

Barley crop is drought resistant and can grow under short water resources and tolerates salinity as reported by (Morales *et al*., 2009; Lacolla et *al*., 2008; Epsten *et al*., 1980). While the variation in plant height between treatments was due to competition for light; thus light interception effect under intercropping is more severe and adversely affected plant growth as reported by (Kessler and Breman, 1991; Rosenberg *et al*., 1993; Sato and Dalmacio, 1991).While the significant of biomass dry weight under intercropping treatments in 2018, was attributed to favourable site conditions for barley under the intercropping than in the control plots. In this respect, generally soil fertility in terms of N, P and Kwere higher at upper layer (0-30cm) of intercropped plots besides Na, while Organic Carbon was been higher under lower layer at 30-60 cm. Similarly for the other elements such as pH, CaCo3, Mg and SAR were been lower at upper layer as well as C/N as was shown in our study in tables 6 and 7. Besides that soil salinity was decreased at the top soil layer particularly in the intercropped plots as indicated in the mentioned above tables in our study. Other works such as Belsky *et al*(1989) found that P N K and Ca were greater under tree canopy than open areas. Trees such as *Acacia tortilus* and *Adansonia digitata* their canopies were reduced solar irradiance by 45-65 % and soil temperature by 5-11 C º. So, salinity is not determinant factor under this agro forestry system, since salinity increases with increasing depths. Besides that barley has shallow roots system that minimized interface effect with intercropped trees and usually used for soil reclamation as stated by (UCSAREP, 2006).In this regard as cash winter crop barley can substitute other fodder crops that require more water such as Bersim (*Medicago sativa*) as reported by Mohammed (2009). However, in Northern Sudan at Merowe site, the barley production per ha is 5000 kg as fodder crop as stated by (Hamada *et al*., 2017).While under Gazeira Scheme environment of the Sudan barley yielded 3.7 ton per ha as reported by Salih (2006). Whereas Khair *et al* (20011) reported that a barley crop was needs low water quantity but cool temperature to yield high dry matter.

Land equivalent ratio (LER) was higher under this agro forestry system which indicates that intercropping is advantageous. That obviously observed in the second season where *Grewia tenax* trees were becoming vigorous. Similarly Nasre Aldin *et al* (2011) reported that LER was been more advantageous in intercropping of *Acacia senegal* with field crops such as sesame, sorghum and millet due to different proportions of crop and gum yield.

Conclusion

Therefore it can be concluded that*Grewia tenax* tree growth in terms of tree height, collar diameter and crown diameter was higher under intercropping particularly wider spacing (GS2) under 1.5 m. While fruit yield was higher under sole trees of *G.tenax.* Barley crop biomass was higher under intercropping particularly under wider spacing (GS2) than control one.Land equivalent ratio was higher under this agroforestry system particularly under wider spacing (GS2).Soil fertility in terms of N, P and K increased with soil depths and improved in the upper layers at the intercropped plots when compared with open areas. In this respect, farmer can obtain good earnings in terms of fodder from the barley that maintains his animals. Moreover, with little water source and effort farmers can obtain fodder crop of highly nutritive value from barley crop. And also the farmers can obtain fruits yield from the trees in terms of Geduim (*Grewia tenax*) which considers as a cash crop of high nutritive value and popular for medication from many malnourished diseases. Thus the fruit is rich in iron element and used in refreshing drink and very expensive in terms of price. Besides *G.tenax* trees have other functions such as fodder, carbon sequestration and in halting desertification in these poor marginal soils lands.

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